

# ***Achieving Digital Integration Using the HART Protocol***

**Unleashing the Power of HART  
in Your System**

# Current Situation

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- **All industry users working to:**

- Improve Process Operations
- Better Manage Plant Assets
- Increase System Availability/Reliability

- **Many faced with declining budgets and pressure to do more with less**

- **Much of the solution may already be in your plant**

- Much of the Power is already in your smart field devices enabled by HART technology
- New control system interfaces leverage the intelligence in your HART smart devices to deliver continuous Real-Time Diagnostics and much more!

# Things You May Know About HART

- Most smart instruments use HART Communication
- HART smart field devices are used interchangeably with traditional 4-20mA analog only units
- Hand Held Communicators are often used to perform device set-up, calibration, commissioning and periodic maintenance
- PC-based instrument management tools can remotely communicate with HART devices to manage calibration and other instrument parameters from central locations (instrument shop or control room)

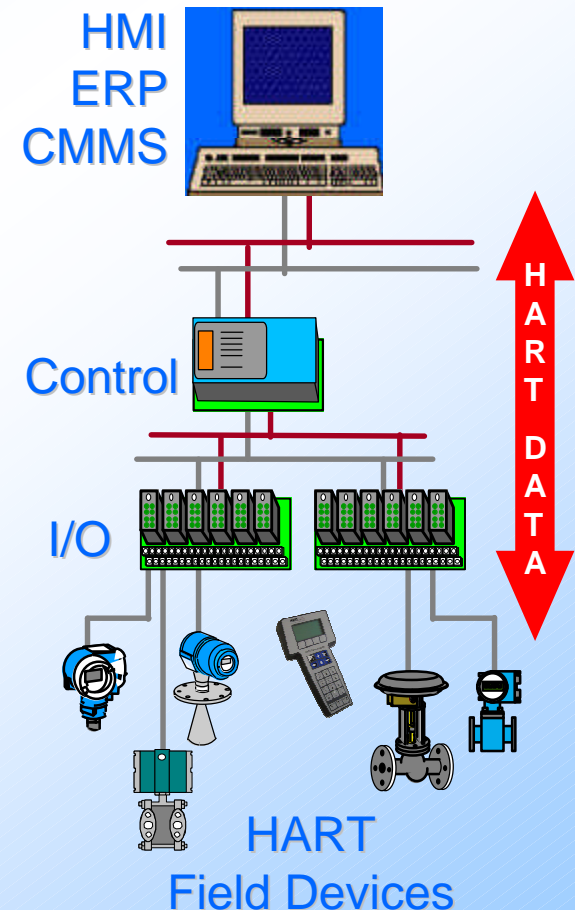


***HART = Savings in Installation & Maintenance***

# Things You May Not Know About HART

- All HART smart devices provide process data for plant operation continuously - 24/7
- HART communication provides access to all device data simultaneous with the 4-20mA analog signal being used for control
- Diagnostic status information pertaining to the health of the field device and quality of the 4-20mA signal is part of every message
- The Primary Variable (PV) is transmitted as a 4-20mA signal and also as a digital value
- Many devices are Multi-Variable and have measured or calculated process variables in addition to the PV

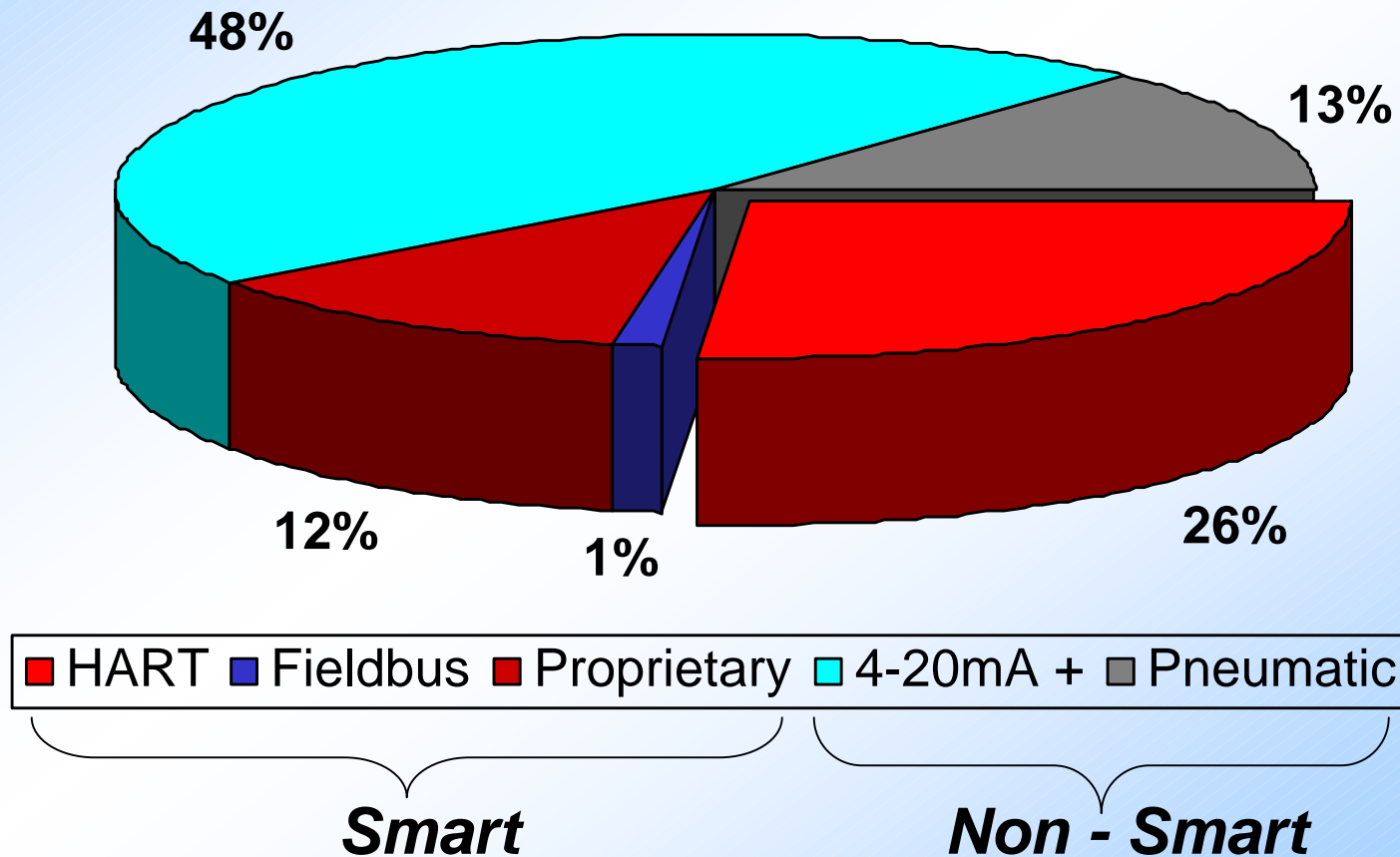
*This Data is Valuable \$\$\$*



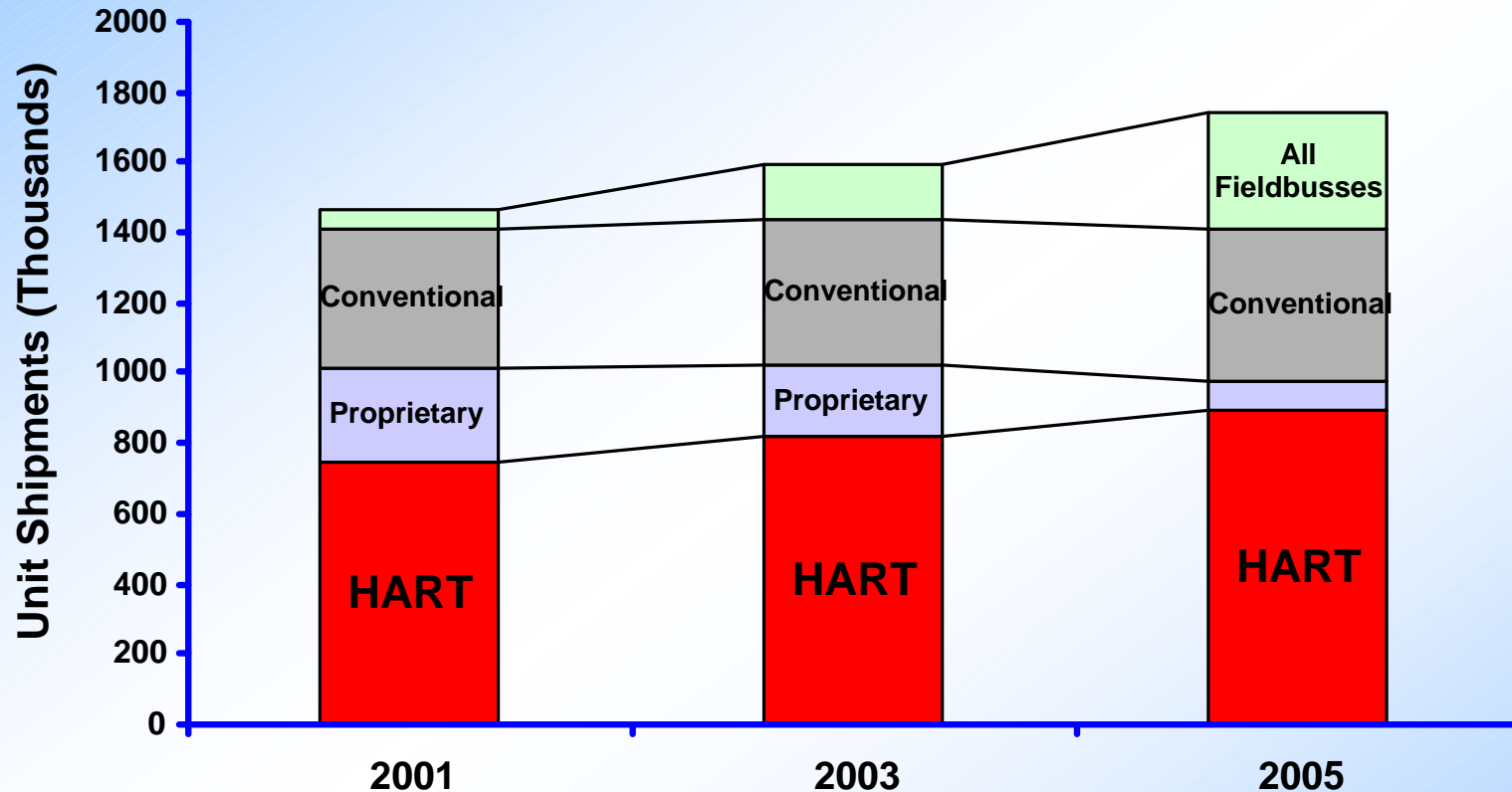
# Worldwide Installed Base

*Field Devices - Press, Temp, Flow, Level, Valve Positioners, Analytical*

**40-45 Million Devices**



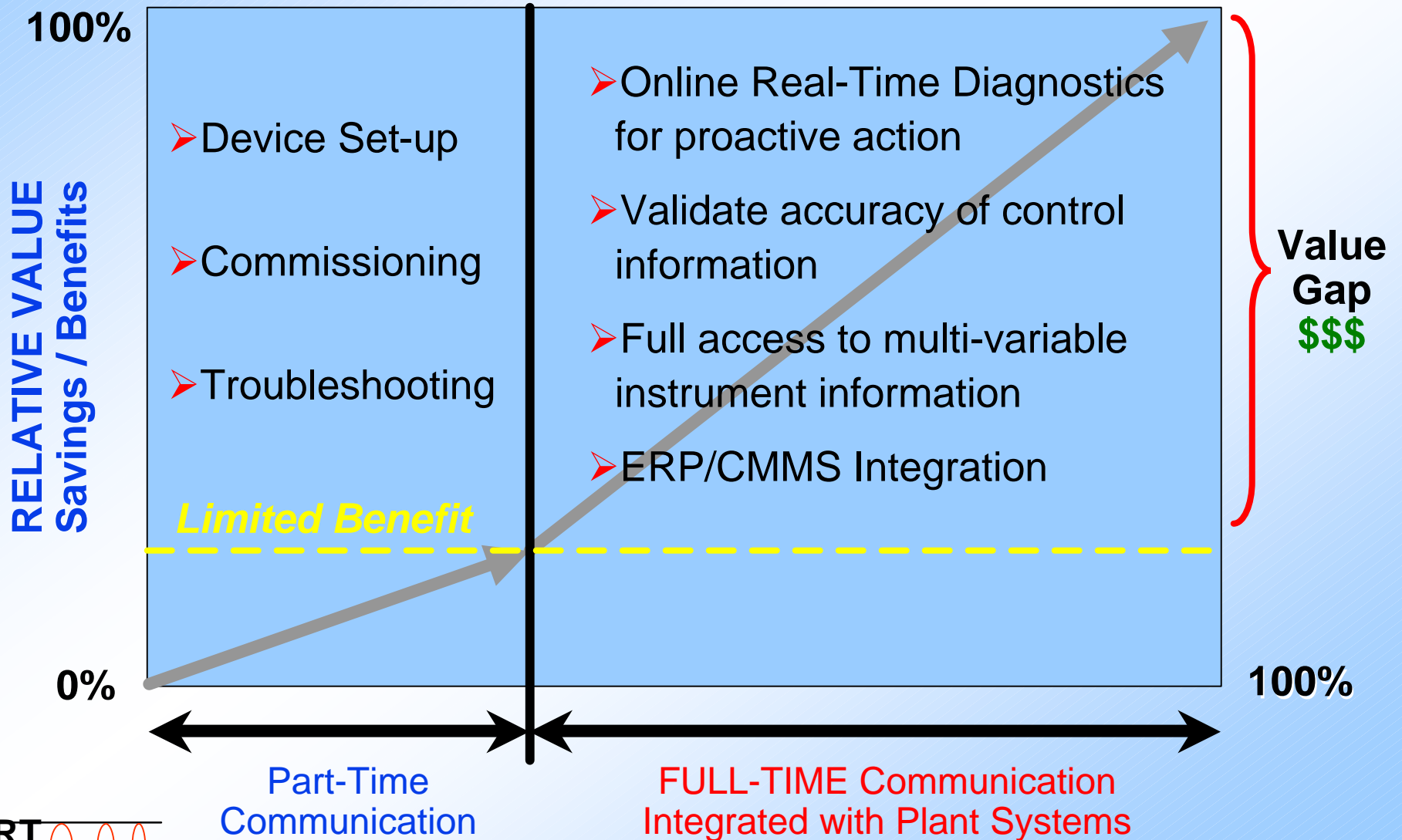
# Worldwide Pressure Transmitter Outlook



***The Installed Base of HART is Huge and  
It will continue to grow for a long time to come !***

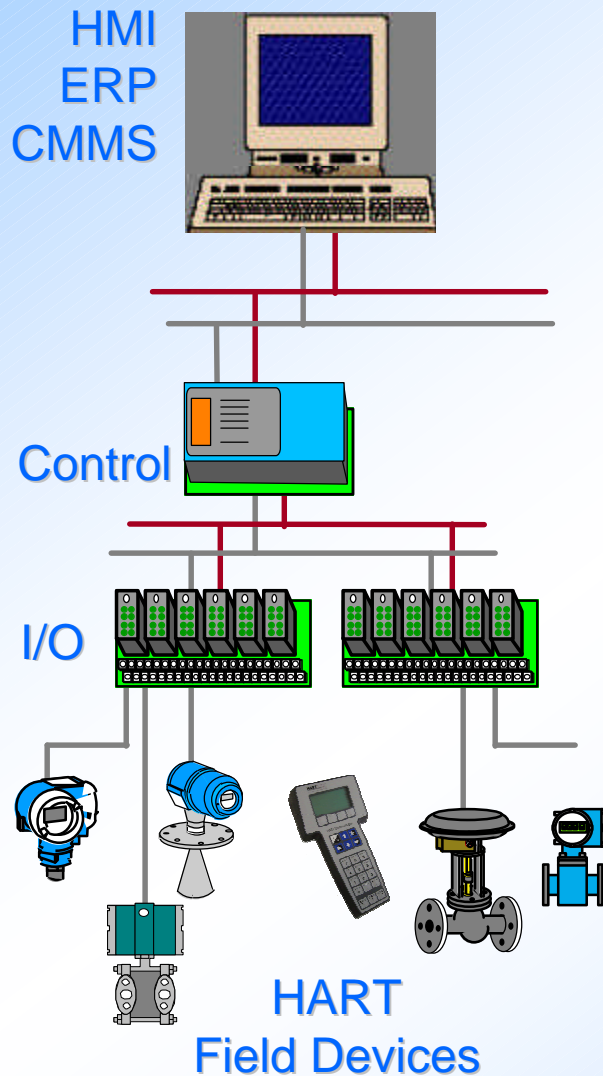
Source: 2001 Pressure Transmitter Worldwide Outlook Study  
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# Unleash the POWER of Your HART Smart Instruments





# HART Digital Integration



- **HART Communication integrated with plant control and safety systems**
- **Systems communicate with HART devices “full time” - analog + digital**
- **Operators alerted to impending problems before negative impact to the process**
  - Accuracy of data exchange between field device and control system validated continuously
  - Any deviation between field device and system (loop current, range values, etc) detected immediately
  - Real time device diagnostics
- **Additional process data in Multi-Variable devices used to improve plant operation**



# ***HART Basics***

**An Introduction to the HART Protocol**

# What is HART ?

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*HART is a backward compatible enhancement to 4-20mA instrumentation that allows two way communication with smart, microprocessor-based field devices.*

## ■ HART Characteristics

- **Simultaneously supports two communications channels**
  - » 4-20mA "analog" communications and
  - » Modulated two-way "digital" communications.
- **Extensive Standardized Application Layer Data**
  - » Device status and diagnostics;
  - » Cyclical process data including: floating-point digital value, engineering units and data quality / status; and
  - » Field devices can continuously publish their process data.
- **Standardized Operating procedures (e.g., for loop test, current loop re-ranging and transducer calibration).**

# The HART Specifications

## Organization of Specifications

### The Protocol

HART Field Communications Protocol Specification  
HCF\_SPEC-12, Revision 6.0

### Physical Layer

FSK Physical Layer Specification  
HCF\_SPEC-54, Revision 8.1

C8PSK Physical Layer Specification  
HCF\_SPEC-60, Revision 1.0

### Data Link Layer

Data Link Layer Specification  
HCF\_SPEC-81, Revision 8.0

### Application Layer

Command Summary Specification  
HCF\_SPEC-99, Revision 8.0

Universal Command Specification  
HCF\_SPEC-127, Revision 6.0

Common Practice Command Specification  
HCF\_SPEC-151, Revision 8.0

Device Families Command Specification  
HCF\_SPEC-160, Revision 1.0

Common Tables Specification  
HCF\_SPEC-183, Revision 13.0

Block Data Transfer Specification  
HCF\_SPEC-190, Revision 1.0

Command Response Code Specification  
HCF\_SPEC-307, Revision 5.0

## ■ Collection Of Specifications

- Easy-to-Read Language
- Consistent and well-defined terms
- Controlled by HART Communication Foundation

## ■ Provide Clear Complete Definition of the HART Protocol

## ■ Open and Available to Anyone

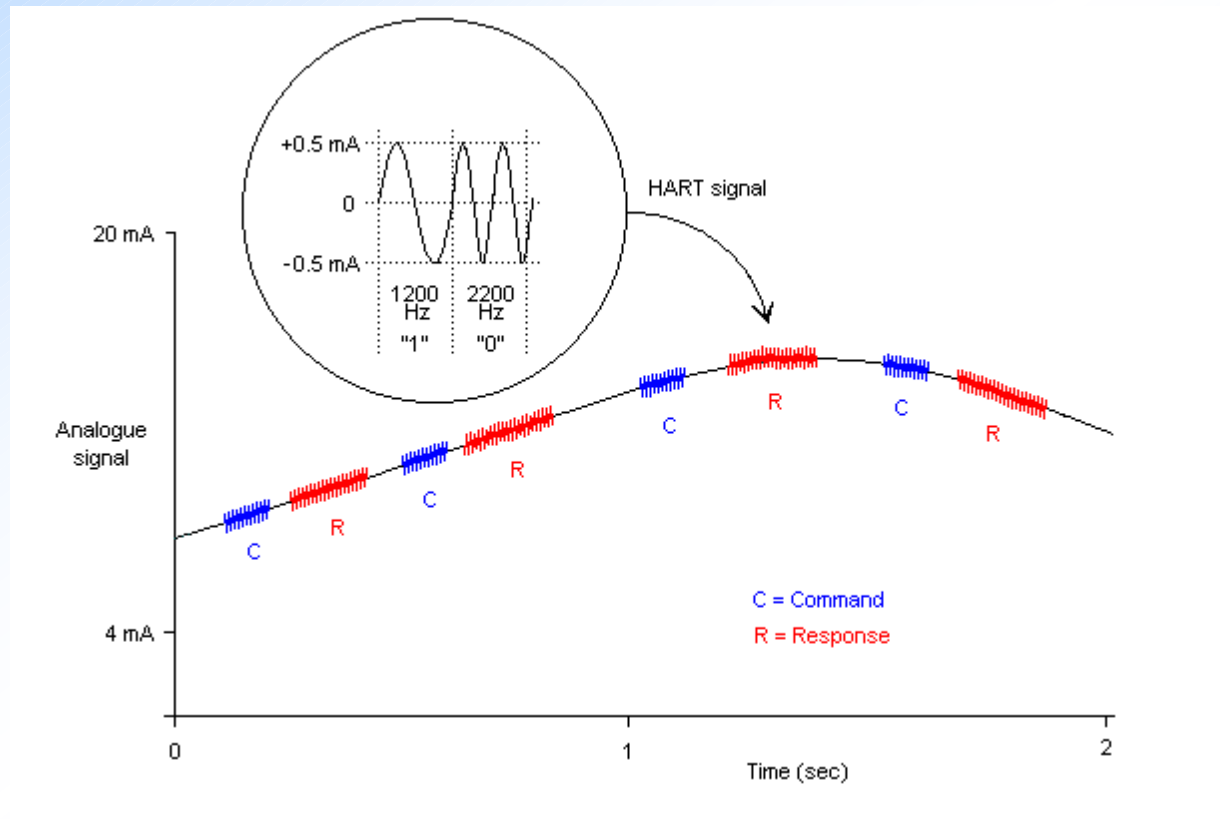
# HART Protocol Layers

	OSI Layer	Function	HART
7	Application	Provides the User with Network Capable Applications	Pre-defined Data Types; Standardized Status, Process Data and Procedures
6	Presentation	Converts Application Data Between Network and Local Machine Formats	
5	Session	Connection Management Services for Applications	
4	Transport	Provides Network Independent, Transparent Message Transfer	
3	Network	End to End Routing of Packets. Resolving Network Addresses	
2	Data Link	Establishes Data Packet Structure, Framing, Error Detection, Bus Arbitration	Secure Data Exchange; Token Passing Network; Multiple hosts and field devices.
1	Physical	Mechanical / Electrical Connection. Transmits Raw Bit Stream	Modulated Digital Signal. Simultaneous 4-20mA and HART Communications

- **Uses OSI Reference Model as a guide**
- **Specifications promote interoperability**
  - Requirements in each layer clearly specified
  - HART Compatible devices must support all layers

# HART Physical Layer

**HART allows *additional information* to be carried on the same pair of wires with the 4-20 mA Analog Signal**



***Simultaneously and Transparently***

# Physical Layer Features

## ■ 2 Communications Channels

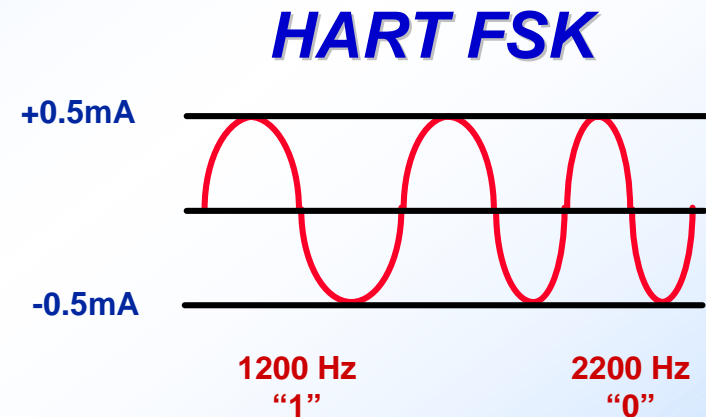
### 1 Pair of Wires

- Digital Data Modulated on the Analog 4-20mA Current Loop
- Simultaneous and Transparent Communications

## ■ Standard 4-20mA wiring

## ■ Backward Compatible With 4-20mA Analog Instrumentations and Systems

- Allows HART Capable Instruments to be added to existing systems
- HART Capabilities can be utilized incrementally
  - » 4-20mA Replacement Instrument
  - » Commissioning, Maintenance
  - » Continuous Real-time Communications
  - » Full Digital Integration





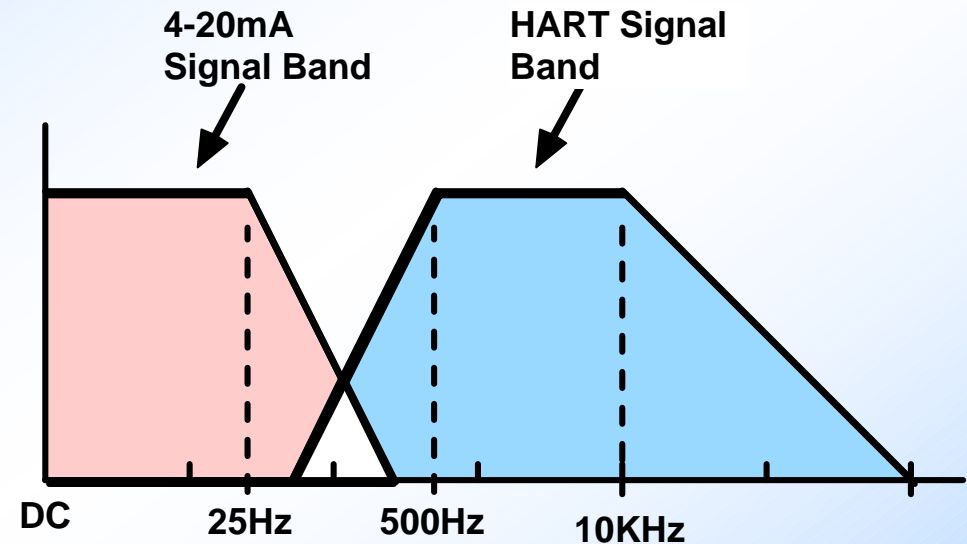
# Two Communications Channels

## ■ Channels Separated in Frequency

- Like Channels on a Television
- Physical Layer Specification
  - » Ensures channel separation
  - » Ensures simultaneous communication

## ■ 4-20mA "Analog" Channel

- One-way communication of one process value
- 4-20mA Analog support large part of Protocol Specifications
- Simple Low Pass Filter isolates 4-20mA signal
  - » HART looks like noise to most existing systems.



## ■ HART "Digital" Channel

- Two-way Communications
- Compliments 4-20mA
- Based on Analog Telephone Modems
  - » Long Cable Runs
  - » High Noise Immunity
  - » You can "hear" HART

# HART Physical Layer Rules

Networks must have at least one, (and typically) only one, low impedance device.

Note: Total loop resistance must be between 170 and 600 Ohms

A network must have no more than one device varying the 4-20mA signal.

Only one secondary device is allowed.

Cable run lengths to 3000m for single pair cable and 1500m for multi-conductor cables is typical.

Note: Actual length depends on the number of multi-dropped field devices and the quality of the cable used.

Low capacitance shielded twisted pair cable is **strongly recommended**.

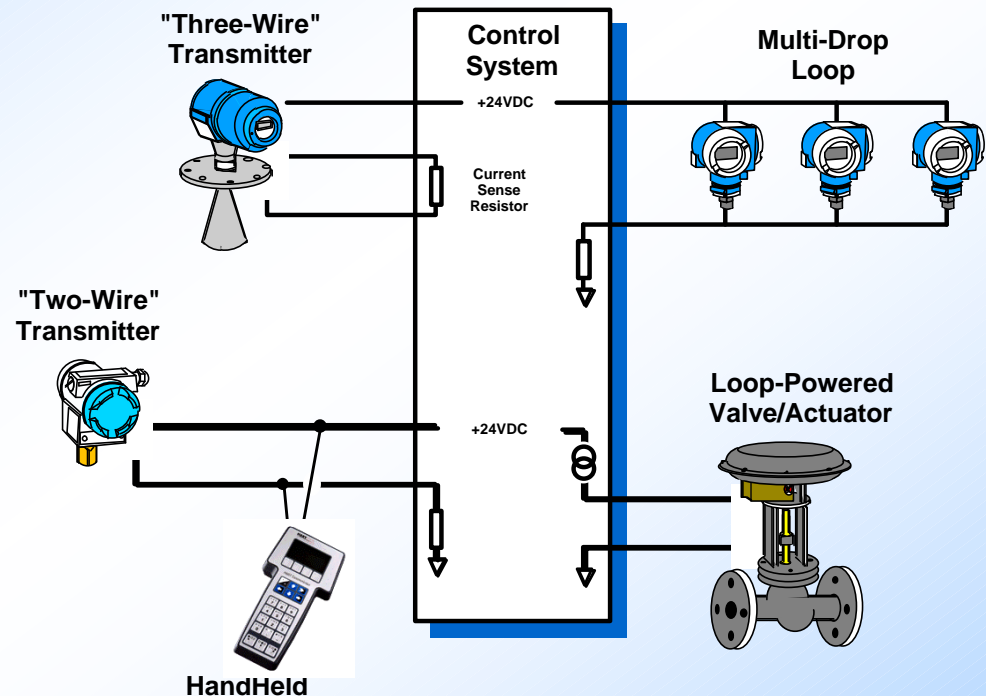
Note: HART has been successfully used over poor quality, unshielded wiring.

Linear power supplies recommended.

HART is compatible with I.S. rules and HART communicates across most I.S. barriers.

**Zener diode barriers** work with HART (They normally allow two-way communications).

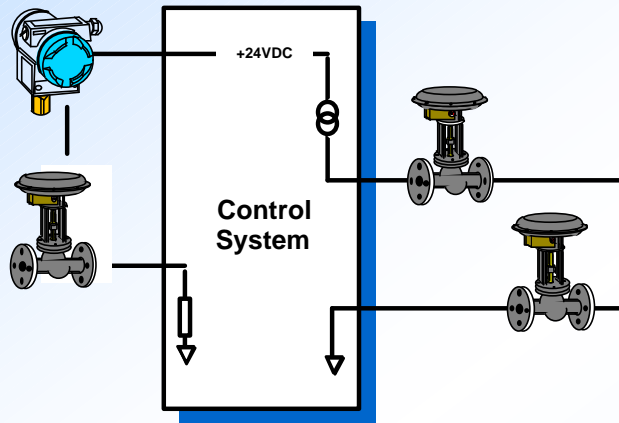
**Isolating barriers** must be HART compatible (i.e., some isolating barriers support one-way communication only).



- Network setup simple and compatible with standard 4-20mA wiring practices
- Many instrument types and network topologies allowed

# Other Network Topologies

## *Closed Loop (e.g., PID) Control*



## *Split-Ranging Valves*

- Like a Single Loop Controller
- 4-20mA Signal drives the loop
  - PID in transmitter  
4-20mA is Control Signal
  - PID in actuator  
4-20mA is Process Signal
- HART used to monitor and provide supervisory control
- Leverages both HART's two communication channels
- Normal 4-20mA Signaling
- HART Access to both valves
  - Re-ranging
  - Adjusting Valve Action
  - Monitor Both Valves' actual position

# The HART Data Link Layer

- **Converts Physical Layer Signals into Data**
  - All HART data is grouped into 8-Bit Bytes
- **Organizes the Data in to Message Frames**
  - HART Messages or Frames Consist of Delimiter, Address, [Expansion,] Command, Byte Count, [Data,] and Check Byte Fields
- **Uses Addresses to Ensure Delivery to the Correct Network Device**
  - HART Masters have a 1-Bit Address
  - HART Slaves have a 4-Bit and a 38-Bit Address
- **Provides Error Detection and Management**
  - HART uses a "Single Parity Check Product (SPCP) Code" i.e.
    - » Odd Parity on Each Byte and
    - » A Check Byte at the End of the Message
- **Controls Device Access to the Media**
  - HART is Token-Passing with Each Message Implying the Passing of a Token to Another Device

***Objective: Reliable Transport of Data  
Across the Physical Layer***

# Example Transaction

- **Half Duplex - Only One Device Talks at a Time**
- **Analog Signaling of Digital Data -**
  - Receiver must Synchronize to the Incoming Analog Signals
- **Sequence:**
  - Carrier Ramps Up
  - Preamble Synchronizes Physical Layer (Demodulator and Receiver)
  - Message Tranferred
  - Carrier Ramps Down
  - Repeat for Slave Reply





# The HART Message Packet

Delimiter	Address	[Expansion]	Command	Byte Count	[ Data ]	Check Byte
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- **Delimiter** - First byte of the message. Tells message framer where the Byte Count is. Indicates the Message Type.
- **Address** - Indicates the master and slave conversing. 5 bytes long, unique address. Indicates the master and slave communicating
- **Expansion** - 0-3 bytes reserved for protocol enhancements.
- **Command** - Tells the Application Layer what information is being transferred or action being performed.
- **Byte Count** - Tells message framer where the Check Byte is and the Application Layer how much information is being transferred.
- **Data** - The message "Payload".
- **Check Byte** - An XOR of all message bytes starting with the Delimiter.



# Communication Reliability

## ■ Physical Layer

- Worst case 1 Bit Error in 10,000 (BER  $10^4$ ) (Very Noisy Wire)
- Most applications BER  $\gg 10^6$

## ■ Data Link Layer

- Simple to implement, very robust Error Detection
  - » Parity on each byte
  - » Check Byte on whole message
- Probability of undetected error:

**Less than 1 in 200 years**

## ■ More Reliability Features

- Unique Addresses = Right Field Device gets the message
- Few Delimiters (Start Byte) = Message is Framed Right
- Application Layer has even more checks.

# Accessing a HART Network

## ■ Implied Token Passing

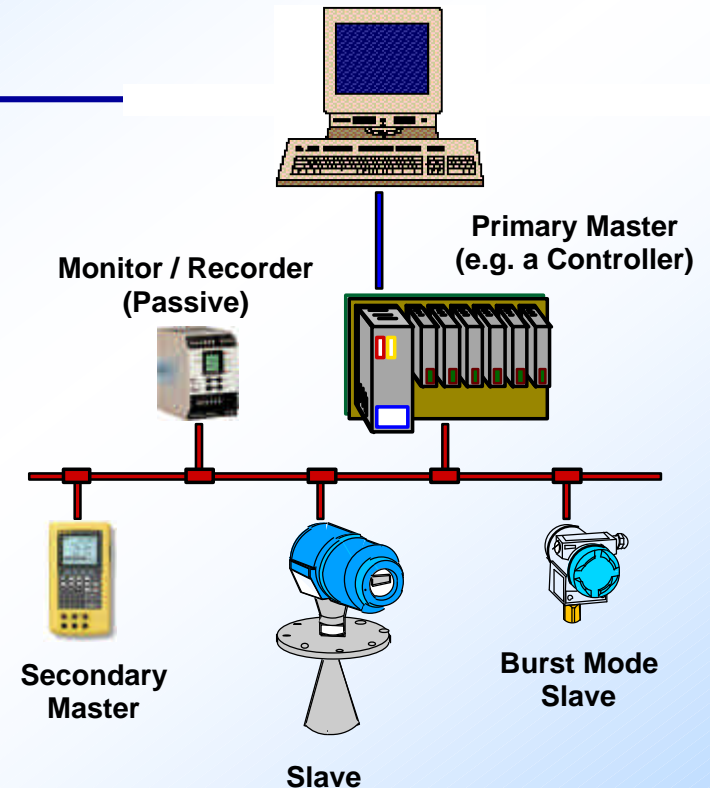
- Relatively Simple to implement
- Each message indicates who talks next
- Masters and Burst-Mode Slave take turns sharing the network
- Not all Actors need be present  
Timers control token recovery

## ■ Most Networks a 4-20mA loop with a single HART Field Device

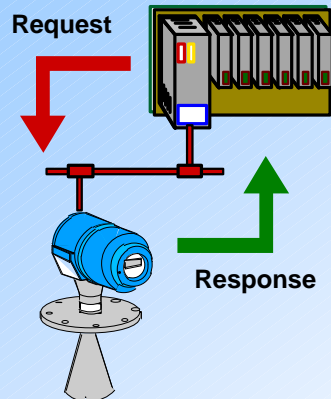
- Usually Silent until Master Talks

## ■ The Players:

Actor	Qty	Description
Primary Master	0-1	Can Initiate a transaction. Has access to the network before the Secondary Master
Secondary Master	0-1	Can Initiate a transaction. Same access rules as Primary (only one timer value is different)
Slave	1-n	Only responds to Master requests
Burst Mode Slave	0-1	Publishes Process Data; Responds to master requests; PLUS (if present) controls network access.
Monitor	0-n	Listens to the network (e.g., captures process data published by burst mode slave)

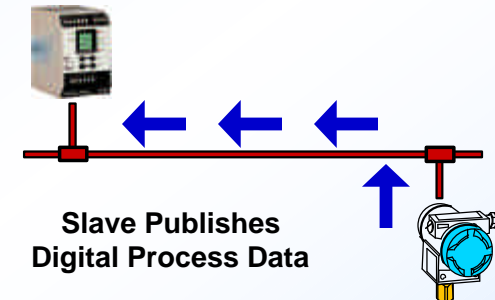


# Two Types of Transactions



## Request / Response ( "Master / Slave" )

- Slave device only communicates when requested
- Responds to Master Command
- "Grant Time" used to allow access by other Master
- 2-3 Transactions per Second



## Burst Mode (Publishing Process Data)

- Optional Slave Support (> 65%)
- Slave continuously transmits selected command response
  - Only Process Data Commands (i.e., 1, 2, 3, 9, 33) may be burst.
- "Grant Time" used to allow access by designated Master
  - Master performs usual Request / Response Transaction
- 3-4 Transactions per Second

# HART Network Access Rules

## ■ Network operates in one of two modes:

- "Normal" mode: master gets token implied by slave response other master
  - » Master recovers lost token using timers
- "Burst" mode: master gets token implied by burst message to other master
  - » Burst mode slave recovers token

## ■ Masters must wait after Connecting to the Network

- Ensures no collisions
- "Synchronizes" Master
- Then master can issue a slave request message
- Master stays Synchronized as long as Connected

### *Typical Master Communication Sequence*

1. The master connects to the channel.
2. After the "Link Quiet" timeout the master becomes synchronized to the channel.
3. Master obtains the token when: (A) the timer expires; or (B) a token pass implied by the message on the network
4. Once the master has the token and must begin a transmission with the "Hold" time.
5. Once the message is sent, the slave is required to begin its response within Slave Time Out".
6. The slave transmits a reply and the master starts the "Link Grant" timer.
7. If there is no other master then the "Link Grant" timer expires.
8. The master must begin another transmission (i.e., go to step 4)

# The HART Application Layer

Delimiter	Address	[Expansion]	Command	Byte Count	[ Data ]	Check Byte
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- **Mission: Correct Exchange of Information**
  - Data Link Layer: Error-free transport of data
  - Application Layer: Does the data make sense?
  - Response Codes Indicate Correctness of master request
- **Specifies**
  - HART data types
  - Classes of commands:
    - » Universal Commands
    - » Common Practice Commands
    - » Device Family Commands (Extention to Common Practice)
    - » Device Specific Commands
  - Standard Device and Process Data Status
  - Standard Operating Procedures (e.g., Re-ranging, Calibration)

***10 Protocol Specifications are Application Layer***



# Some HART Commands

## Universal Commands

Cmd	Description
0	<b>Read Unique Identifier</b> Uses the "polling address" to establish a connection with the field device.
1	<b>Read Primary Variable</b>
2	<b>Read Loop Current And Percent Of Range</b>
3	<b>Read Dynamic Variables And Loop Current</b> Reads the loop current, PV and (if device is multi-variable) SV, TV, QV
6	<b>Write Polling Address</b>
7	<b>Read Loop Configuration</b> Reads the polling address and whether the loop current is active or not.
8	<b>Read Dynamic Variable Classifications</b> Reads the type of each process variable (pressure, temperature, mag-flow, etc.)
9	<b>Read Device Variables with Status</b> Reads up to 4 process variables with data quality status.
11	<b>Read Unique Identifier Associated with Tag.</b> Uses the 8-character tag to establish a connection with the field device
12	<b>Read Message</b>
13	<b>Read Tag, Descriptor, Date</b>
14	<b>Read Primary Variable Transducer Information</b>
15	<b>Read Device Information</b> Reads upper and lower range values and other device related
16	<b>Read Final Assembly Number</b>
17	<b>Write Message</b>
18	<b>Write Tag, Descriptor, Date</b>
19	<b>Write Final Assembly Number</b>
20	<b>Read Long Tag</b>
21	<b>Read Unique Identifier Associated with Long Tag</b> Uses the 32-character tag to establish a connection with the field device
22	<b>Write Long Tag</b>

## Common-Practice Commands

Cmd	Description
34	<b>Write Primary Variable Damping Value</b>
35	<b>Write Primary Variable Range Values</b> Changes primary process variable values used as the 4 and 20ma operating points
38	<b>Reset Configuration Changed Flag</b>
40	<b>Enter/Exit Fixed Current Mode</b> Allows the loop current value to be forced. Used in Loop test and calibrating the loop current (see Commands 45, 46)
41	<b>Perform Self Test</b>
42	<b>Perform Device Reset</b> The device perform a hard reset (i.e., the same effect as cycling the power on and off).
44	<b>Write Primary Variable Units</b>
45	<b>Trim Loop Current Zero</b> Adjusts the loop current to 4ma. Does not affect the range values or the digital primary process value
46	<b>Trim Loop Current Gain</b> Adjusts the loop current to 20ma. Does not affect the range values or the digital primary process value

### Note:

1. All devices must support all Universal Commands.
2. There are many Common Practice Commands. However, the ones listed are commonly used in the vast majority of devices including even the simplest devices available.
3. Commands 0, 11, 21 are three of the Identity Commands. All return the same identity data



# Valuable Data - Simple to Support

The screenshot displays a software interface for configuring a HART device. At the top, there is a toolbar with icons for file operations and a help icon. Below the toolbar, a tabbed menu shows 'Process / Output', 'Device', 'HART', 'Status', and 'Command', with 'Device' currently selected. The main area is divided into two sections: 'Device Info' and 'Sensor Info'. The 'Device Info' section contains fields for 'Message' (CALIBRATED BY JSMITH), 'Descriptor' (MOORE XTC), 'Tag' (PP014), 'Write Protect' (No), 'Date' (11/9/2000), 'Private Label Distributor' (21 Hex), 'Final Assembly Number' (10004), and 'Sensor Serial No.' (1440019). The 'Sensor Info' section contains fields for 'Upper Sensor Limit' (472.50 inH2O), 'Lower Sensor Limit' (-472.50 inH2O), and 'Minimum Span' (9.50 inH2O). To the right of these fields is a 'Standard Procedures' section with four buttons: 'Self Test', 'Master Reset', 'Loop Test', and 'DAC Trim'.

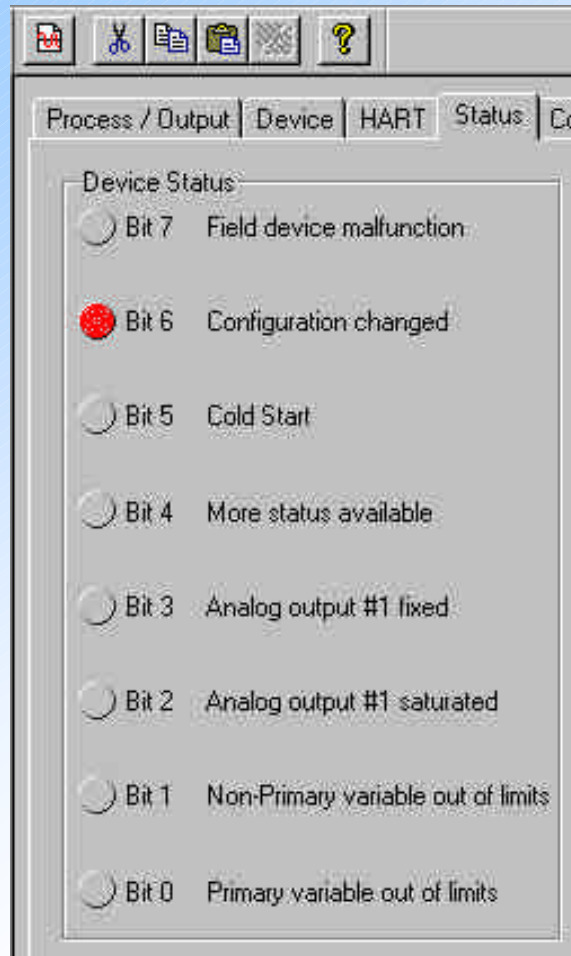
- **35-40 data items Standard in every HART device**
  - **Device Identification**
  - **Basic Calibration data**
  - **Process Variables - both measured and calculated**
  - **Diagnostic Alerts**
- **All Data is easily accessed by HART-enabled Systems**
  - **DD's Not Required**
  - **Accessed the same way in all HART compatible devices**
- **This data is valuable to Improve Operations and Manage Plant Assets**

# Digital Process Variables

The screenshot shows a software interface for configuring a HART device. At the top, there is a toolbar with icons for file operations, a search icon, and a help icon. Below the toolbar is a tabbed interface with tabs for 'Process / Output', 'Device', 'HART', 'Status', and 'Command'. The 'Process / Output' tab is active. Under this tab, there are two main sections: 'Process' and 'Loop Current'. The 'Process' section contains a 'PV' (Present Value) field with the value '0.0522' and units 'inH2O', and a 'Units Select' dropdown menu currently set to 'inH2O'. The 'Loop Current' section contains several fields: 'Analog Value' (4.0092 mA), 'Percent Range' (0.0463 %), 'Upper Range Value' (100.00 inH2O), 'Lower Range Value' (0.00 inH2O), 'Damping' (1.00 Sec), and 'Transfer Function' (Linear).

- Many HART devices are Multi-Variable with more than one process measurement or calculated value
- HART communication provides access to All Process Variables in the device
- Digital Process Variable data includes:
  - IEEE Floating Point Value
  - Engineering Units Code
  - Data Quality Assessment
- The Primary Variable is transmitted on the 4-20mA current loop continuously, but it can also be read as a digital value

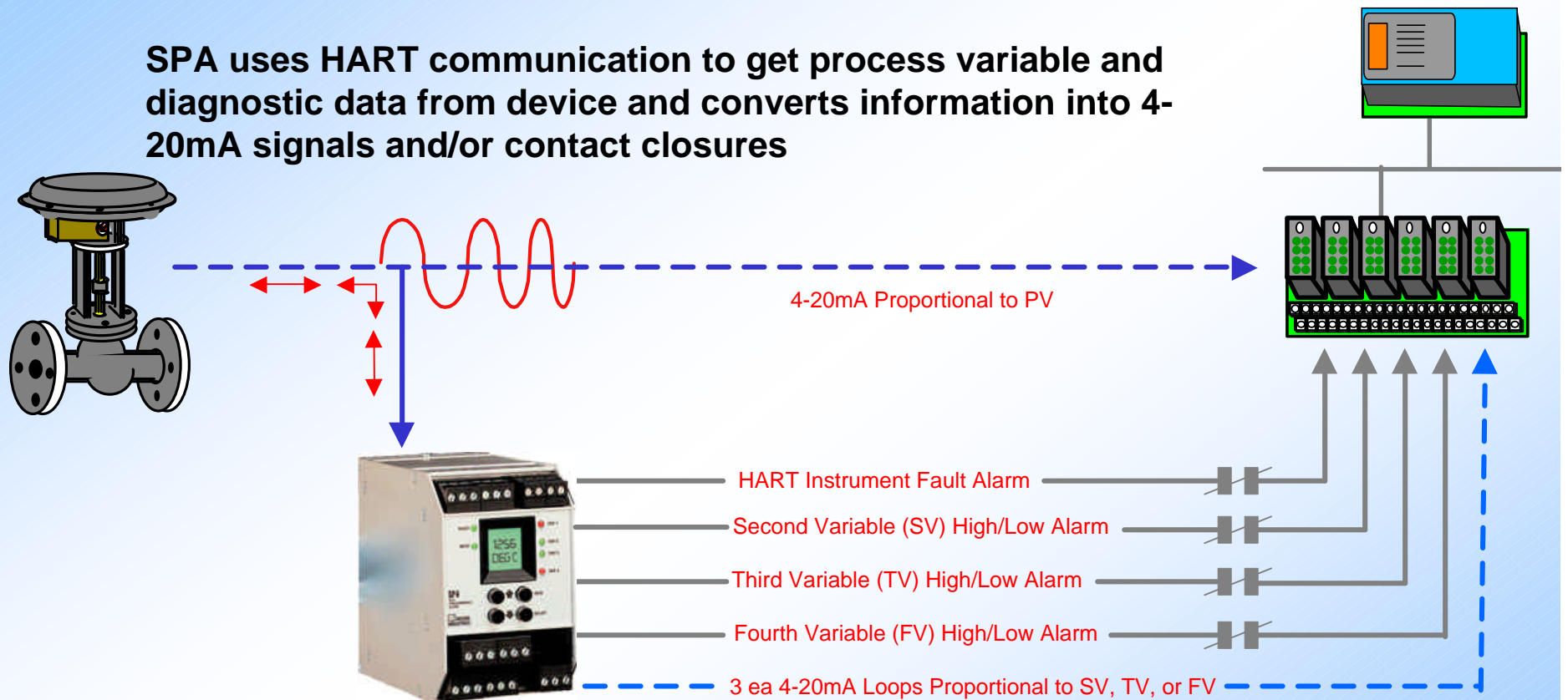
# Status & Diagnostic Alerts



- All HART smart field devices continuously self-assess and monitor their performance
- Diagnostic status information is returned with every message
- Alerts include problems with 4-20mA signal and process variables 'out of limits'
- Continuous communication with field device increases the integrity of control & safety systems
  - Real-time diagnostic alerts provide early warning to problems
  - Detect any miss-match in calibrated Range or Engineering Units between device and system
  - Secure 4-20mA communication channel to ensure accurate transfer of control information

# Easy to Use in Even Simple Hosts

SPA uses HART communication to get process variable and diagnostic data from device and converts information into 4-20mA signals and/or contact closures



*One Wire from Field to Control Room*

*Multiple Analog Signals and Alarm Contacts to the Control System*

# ***HART Digital Integration***

## **Benefits of Full Time HART Communication**



# Consider the Possibilities

## Today

- Millions of HART Compatible Field Devices Already in Plants
- Most installed Systems Don't Support HART
- Only 4-20mA Used Continuously
- Good Value Provided
  - Improve Technician Efficiency
  - Minimize Maintenance Stores
- Existing HART System Support Largely Token
  - Intermittent, Pass-Through HART Communications
  - Focus on Maintenance and "Asset Management"
  - HART Used in Reaction to a Problem
  - Multiplexed I/O Limits Utilization of HART Field Devices

## What Could Be

- Full-Time HART Communication
- Smart I/O Systems
  - Validate High-Speed 4-20mA Communication Channel
  - Support Reporting by Exception
  - Full Access to Multi-Variable Devices
- Control
  - Utilize HART Digital Data
  - Understand HART Status
  - Standardized HART Templates
- Benefits
  - Validated Process Data - Improved Product Quality
  - Reduced I/O Count - 1 Channel per Multi-Variable Field Device
  - Early Problem Detection - Prevent Unscheduled Downtime
  - Lower Maintenance Costs - Fewer Unnecessary Service Calls
  - Improved System Integrity



# All HART Devices Hold a Real-Time Data Base

The screenshot shows a software interface for configuring a HART device. It features a toolbar at the top with icons for file operations and help. Below the toolbar are tabs for 'Temperature', 'Device Variable 0', 'Device Variable 1', 'Device Variable 2', 'Device Variable 3', 'Connection Log', 'Status', 'More Status', 'HART', 'Revision', 'Device', and 'Dynamic Variables'. The main area is divided into sections for 'Process' and 'Range'. The 'Process' section contains fields for 'Dev Var No.', 'Value', 'Units Code', 'Status', 'Sensor Upper Limit', 'Sensor Lower Limit', 'Minimum Span', 'Damping', and 'Sensor Serial No.'. The 'Range' section contains fields for 'Units Code', 'Upper Range Value', and 'Lower Range Value'. The 'Dynamic Variables' section contains fields for 'PV', 'SV', 'TV', and 'QV', each with a 'Value' field, a 'Units Code' dropdown, and a 'Status' field. The 'PV' field is currently set to 1, 'SV' to 0, 'TV' to 2, and 'QV' to 3. The 'Value' fields show real-time data: 32.40 for PV, 14.60 for SV, 2.60 for TV, and 126.40 for QV. The 'Units Code' dropdowns are set to '%LEL', 'degC', 'l\_min', and 'cubic\_meter' respectively. The 'Status' fields are all set to '00'. The 'Sensor Upper Limit' is 500.00, 'Sensor Lower Limit' is 0.00, 'Minimum Span' is 25.00, 'Damping' is 0.00, and 'Sensor Serial No.' is 12345. The 'Upper Range Value' is 100.00 and 'Lower Range Value' is 0.00. The 'Transfer F' field is partially visible. At the bottom left, it says 'For Help, press F1'.

- **All HART Field Devices Continuously Update Their Real-Time Database 24/7**

- You Already Own The HART Devices
- You can Only Get All the Data by Continuous HART Communications

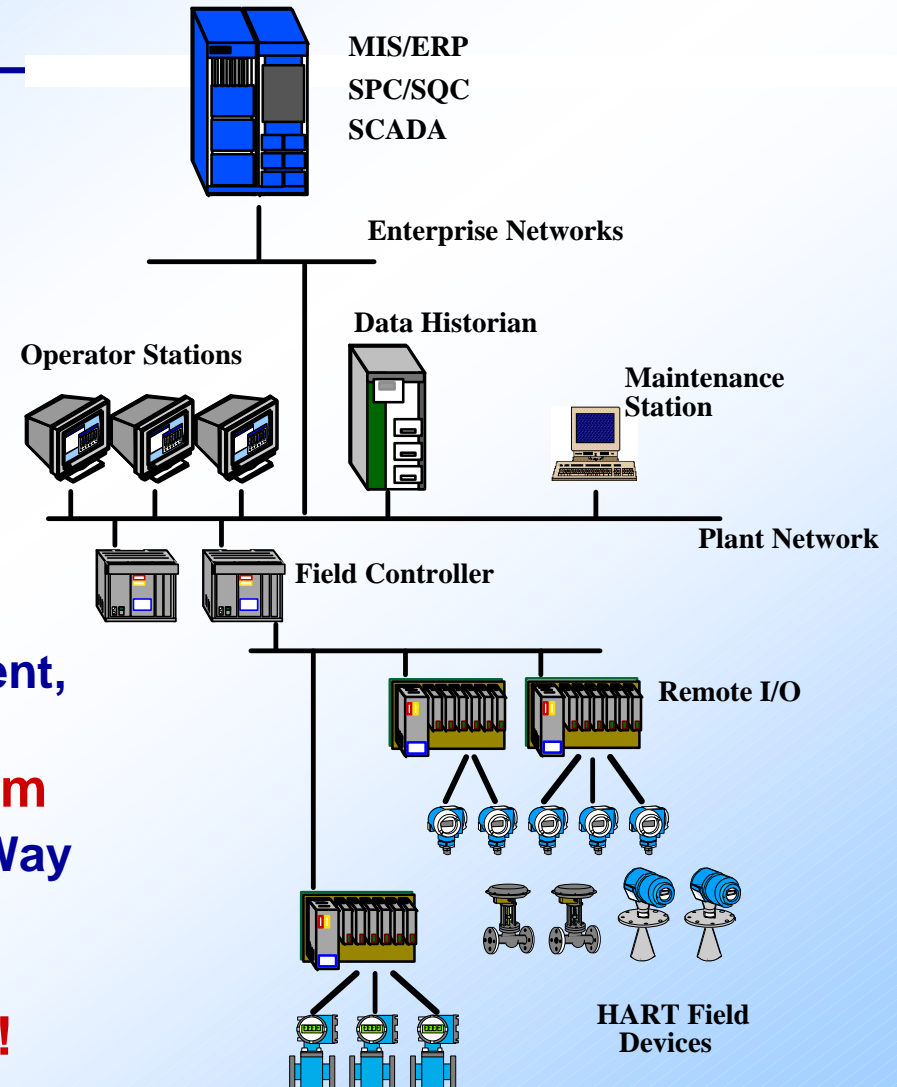
- **HART Instrument is RTU in SCADA System**

- A Different Way of Thinking

- **How does this Fit into System View of an Enterprise?**

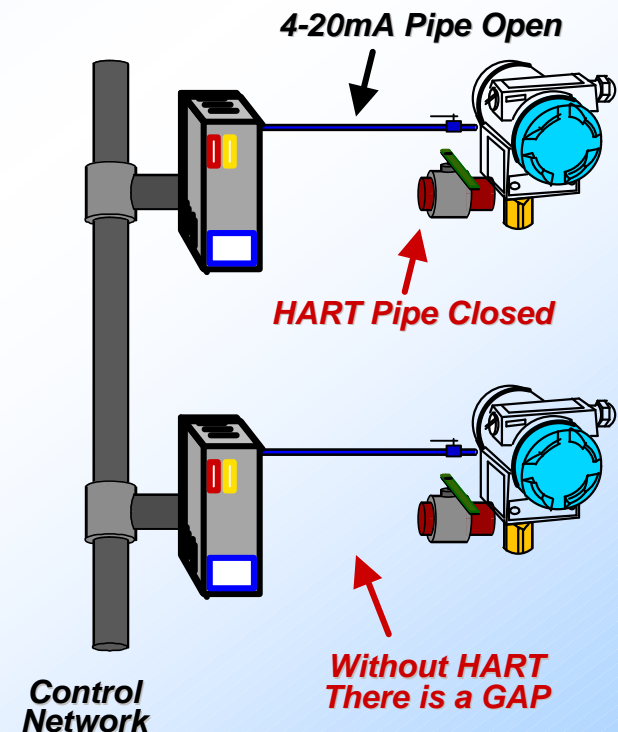
# A System as a Distributed Real-Time Database Application

- **Many R-T Databases scattered throughout the System**
- **Field Device Closest to Process**
  - Its DB Reflect Process Conditions
  - The Rest of System Needs Access to ALL of this Data
- **Other System Components**
  - Have DB with Pieces of Many Field Device Databases
  - Their Copy of the Data must be Current, Accurate, Reliable
- **The Field Device is Part of the System**
  - Not All Control Systems Think This Way
  - Similar to SCADA Thinking
- **HART's Huge Installed Base Already Supports This System View!**
  - HART is How The DB in the Decision Makers is Kept in Sync With the Process



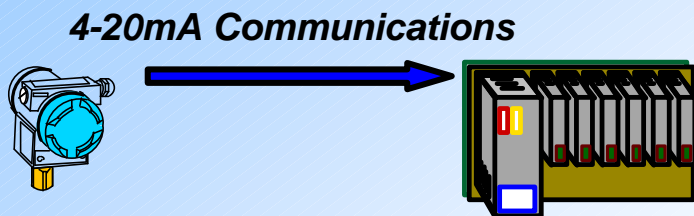
# Field Communications - The Critical Link

- **Reliable, Continuous Communication is Critical to Making Good Decisions**
- **4-20mA Only Support Produces an "Information Gap"**
- **With Many Systems Only 4-20mA Communication is Continuous Real-Time**
  - Only a One Data Item Is Communicated
  - Communications is limited to One Direction
  - Secondary Process Variables, Data Quality, and Real-time Diagnostics . . . Lost.
- **Communications is Not Secure**
  - Distortion in 4-20mA May Not Be Detected
  - Meaning of 4-20mA Signal Can Change
  - Erroneous information if 4-20mA set-up in device and system not aligned

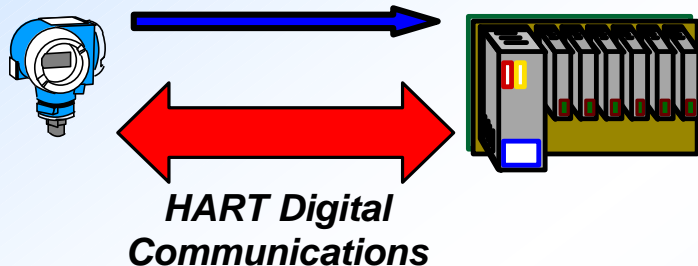


***Continuous HART Communication  
Closes the Information Gap***

# An Integrated HART System vs. 4-20mA Only



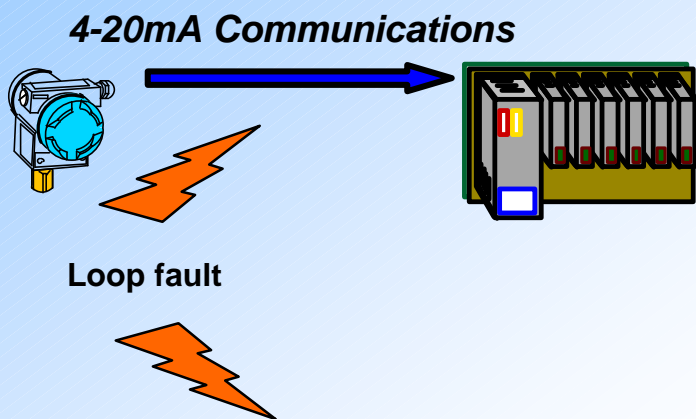
- Highest possible communication rate for a Single Process Value
- 4-20mA control signal must be manually verified
  - Calibration of field device and I/O channel
  - Matching Range for both I/O and device



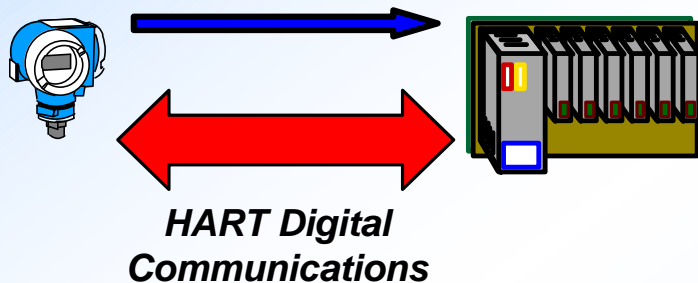
**HART Devices Have Two Communication Channels**

- Highest possible communication rate for a Single Process Value
- HART Communication closes the “Information Gap”
  - Secures integrity of 4-20mA signal
  - System can validate accuracy of the 4-20mA signal and continuously monitor device diagnostics in real-time
  - Enables access to additional information in multi-variable devices

# 4-20mA Signal Validation



- 4-20mA signal from field device may differ from the 4-20mA received at the system
  - Erroneous control signal produced by unexpected external influence
  - Detectable ONLY if signal “out of range”- above 20mA or below 4mA

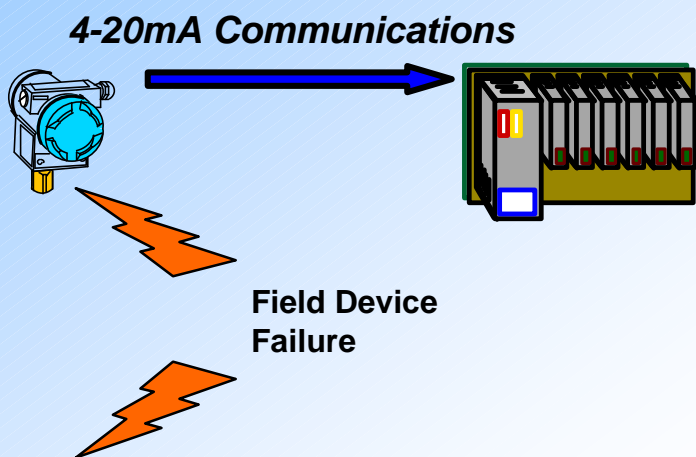


**HART Pass-through Won't  
"Get the Job Done"**

- 4-20mA signal validated continuously
- System automatically detects any disagreement between Field Device and I/O
  - I/O continuously checks loop current for agreement with digital values from device
  - Continuous communication detects any device or process connection problems
  - Automatic calibration of the 4-20mA possible



# Field Device Problem Detection

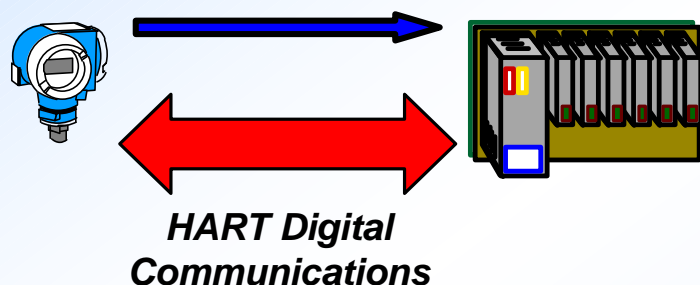


## ■ Only Catastrophic Failures Detected

- 4-20mA signal must be outside normal operating range to detect problem
- Non-catastrophic failure may cause error in 4-20mA signal - temp compensation loss

## ■ Disruption to Process Operation Likely

- Unscheduled downtime or impact to product quality



## ■ Real-time Diagnostic Alerts from Device

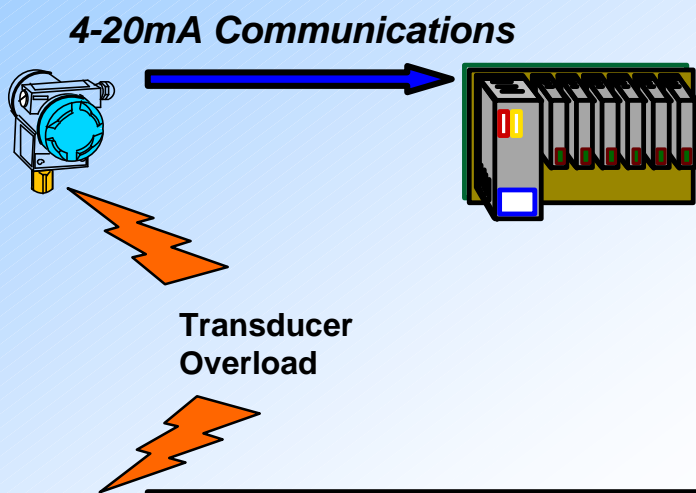
- Extensive self diagnostics - "Device Needs Maintenance", "Valve Not Tracking SP"
- Change in Device Status
- Supports "Self Validating" Devices

## ■ Process Disruption may be Avoided

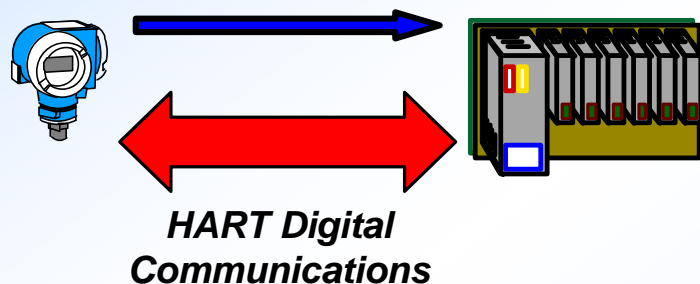
- Operators alerted to problem early
- Enables pro-active action for minimum impact to process operation



# Process Overload Condition

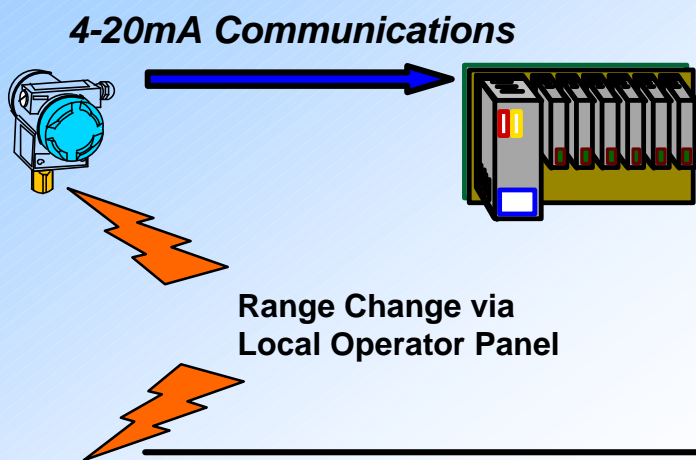


- **Loop Current saturated (e.g. at 3.8 or 20.8mA) or frozen (fixed)**
  - I/O is "Blind" - No usable Process Value
  - Process measurement may simply be Out of Range
- **Manual Inspection Necessary to Diagnose the Problem**

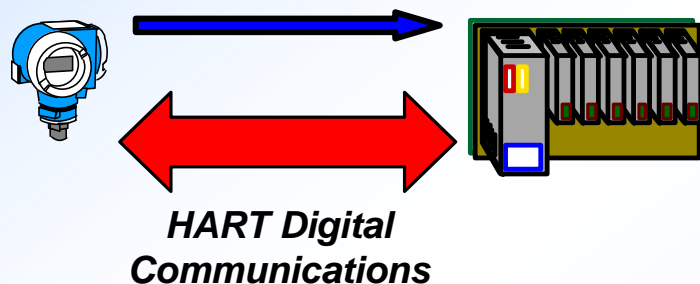


- **Process Measurement still available with HART Communication**
  - I/O can still "See" and provide information for operator display
- **Diagnostic Alerts indicate data quality**
  - "PV out of Limit", "Secondary Variable Out of Limit", "Loop Current Saturated"
  - Diagnosis possible without costly trip to the field

# Change in Field Device Configuration



- Change to 4-20mA signal may NOT be apparent
- Change in operation may NOT be detected



- Status alerts flag any change to parameters
  - "Configuration Changed" flag
  - "Configuration Change Counter"
  - Any configuration change detected immediately
- Supports Multiple Masters and Local Panels
  - "Lock Device" Command to prevent another Master or Local Panel from making changes

# Seven Commands for Digital Integration of HART

## ■ Read the Loop Current

- Command 2
- Does the loop current in the I/O match the Field Device's?

## ■ Read the Process Variables

- Command 3, 9, or 33
- Access to Secondary Variables in Field Device
- Validates Primary Variable sent using the loop current

## ■ Detect Status Change

- Status in Device Response
- Plus any change in Command 48 Data
- Triggers notification of Operator

## ■ Check the Range Value

- Command 15
- Has the meaning of the loop current changed?

## ■ Test and Calibration the Loop Current

- Loop Test with Command 40
- Calibrate (if needed) with Commands 45, 46
- Analog Communication Channel Integrity

## ■ Detect Change in Instrument Configuration

- Status in Device Response (Configuration Changed bit)
- Command 0 (change counter)
- Triggers notification of Operator

# HART Digital Integration - Throughout the System

## ■ One-One Smart I/O

- Ensure Reliable Field Communication
  - » High-Speed 4-20mA Comms
  - » Validate Using HART
  - » Best to detect 4-20mA Errors
- Analog and Digital Data Acquisition
  - » 4-20mA Primary Process Variable (Convert Using HART Range Values)
  - » HART for Secondary Process Variables, Data Quality and Status
- Reporting by Exception

## ■ Field Controller

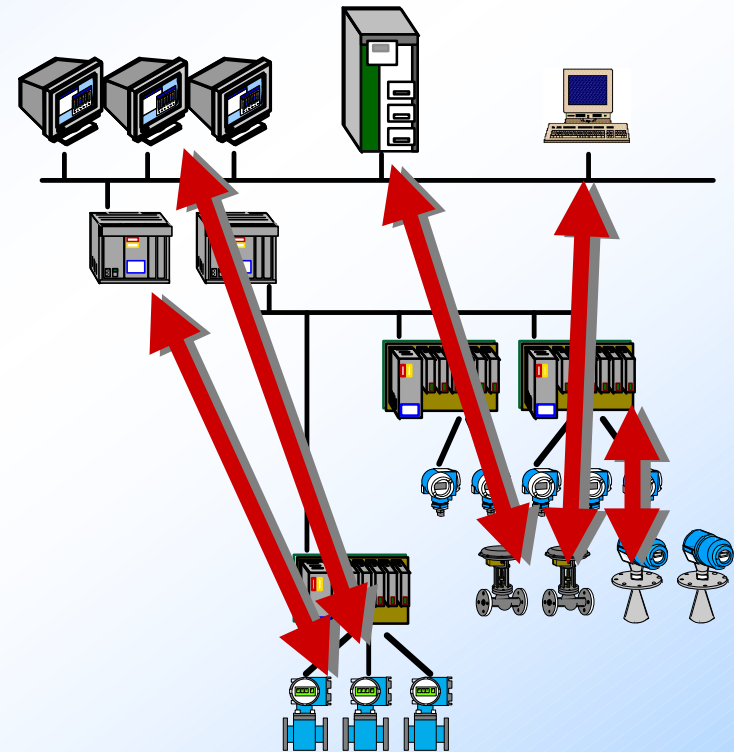
- Utilization of HART Multi-Variable Devices
- Easy Access to and Use of All HART Process Data And Status
- Apply Full Knowledge of Process For Optimization and Control

## ■ Operator Station

- HART Allows Full Window into the Process
- Early Notification of Potential Problems

## ■ Maintenance Station

- Detailed Instrument Configuration DB
- Only one that Needs More than Standard HART Data and Commands



***You Own The HART Devices -  
Use The Data***

# ***Understanding Systems Implementations***



# Capabilities of HART Hosts

- **The application and implementation affect system capabilities**
  - Pass-Through - HART Commands can be communicated but, the component itself may directly Use / Support HART Capabilities
  - Multiplexed I/O - One HART Communication Channel Shared Between many Device Connections. Resulting Communication Painfully Slow.
- **Simple HART features not supported in all Masters**
- **HART Protocol Specifies Master Classifications**
  - Helps Understand HART Capabilities Supported
  - Starting Point for a System Discussion.

Class	Description
0	Host does not meet the minimum requirements of Conformance Class 1
1	The host can utilize cyclical process data from any field device
2	The host can supply the user with basic identification and configuration data from any field device
3	The host can perform basic configuration for any field device - Minimum level for classification as "Generic Host"
4	The host provides basic commissioning and calibration support for any device
5	The host can access all data items and device specific functions for any device



# I/O System Considerations

## ■ HART Data Link Layer Token Passing

- Supports Multiple Masters
- Synchronization Time Required When Connecting to a Channel

## ■ One-One, Buffered I/O

- One Modem - One Network
- Buffered to Avoid Lost Tokens
- Supports Burst Mode
  - » Publishes Cyclic Data
  - » Even Faster Process Data Updates
- Best Access to HART device DB

## ■ Multiplexed I/O

- Shares 1 HART Comm Channel With Many Networks
- Many Times Slower Than Point to Point Communications
- Slower Than HART MultiDrop
- Limits Utilization of Field Device

## I/O System Performance

### *Latency (seconds)*

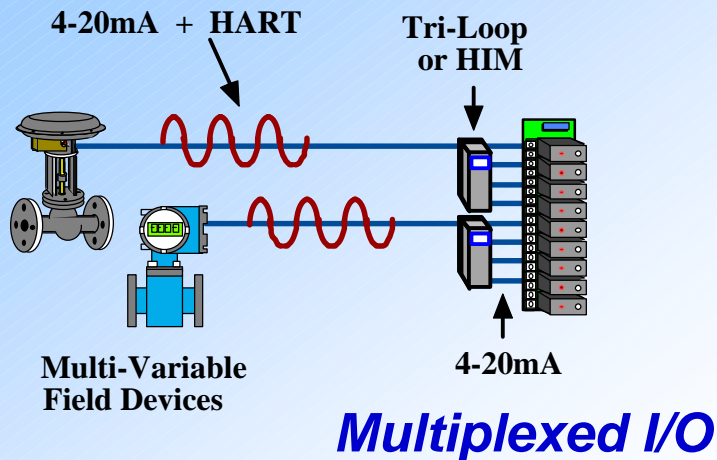
Number Channels	One-One	Point-Point (unbuffered)	Multi-Drop	Multiplexed
1	0.38	1.16	0.38	0.38
4	0.38	1.16	1.51	2.80
8	0.38	1.16	3.02	5.60
16	0.38	1.16	6.04	11.21
32	0.38	1.16	12.08	22.43
256	0.38	1.16	---	179.42

### *Throughput (Transactions Per Second)*

Number Channels	One-One	Point-Point (unbuffered)	Multi-Drop	Multiplexed
1	2.65	1.14	2.65	1.43
4	10.60	4.56	2.65	1.43
8	21.19	9.12	2.65	1.43
16	42.38	18.24	2.65	1.43
32	84.77	36.48	2.65	1.43
256	678.13	291.84	--	1.43

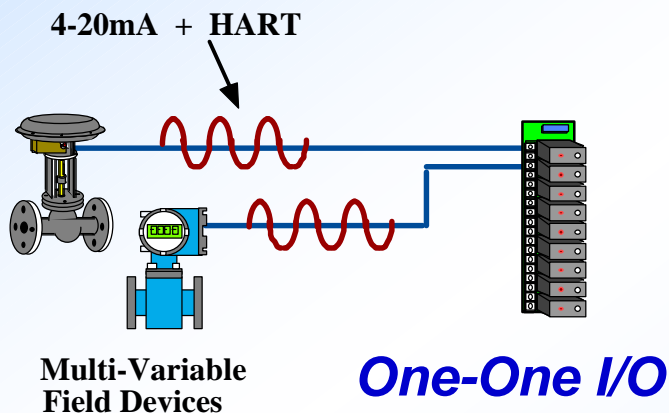
***Be Aware of I/O System Throughput and Latency Statistics***

# Multiplexed I/O With Multi-Variable Field Devices



## *Continuous HART Communication not Practical*

- **Multiplexed I/O Slows HART Access**
  - 5-6 Second (8-Channel Mux) Or More Latency
  - Limits Use of HART Data
- **Multi-Variable Digital Data Access Slow**
  - May Require Adapter for Faster Secondary Variables
  - HART Burst Mode Converted to 4-20mA
    - » Degraded Accuracy / Security
    - » HART Communications Sets 4-20mA Update Rate
  - Wasted I/O Channels
  - More Hardware and Complexity



- **True Continuous HART Communication**
  - 0.5 Second Latency
  - Full Access to All Field Device Information
  - Closes the Information Gap
  - 4-20mA Communication Security Enhanced
- **Multi-Variable Digital Data Access Practical**
  - Secure Digital Process Data with Status
  - Saves I/O

*Maximizes Return on Investment*

- **The Reliable, Simple System**

# The Maintenance Station "Add-On"

## ■ Easiest Way to Add HART Support to a Conventional Analog System

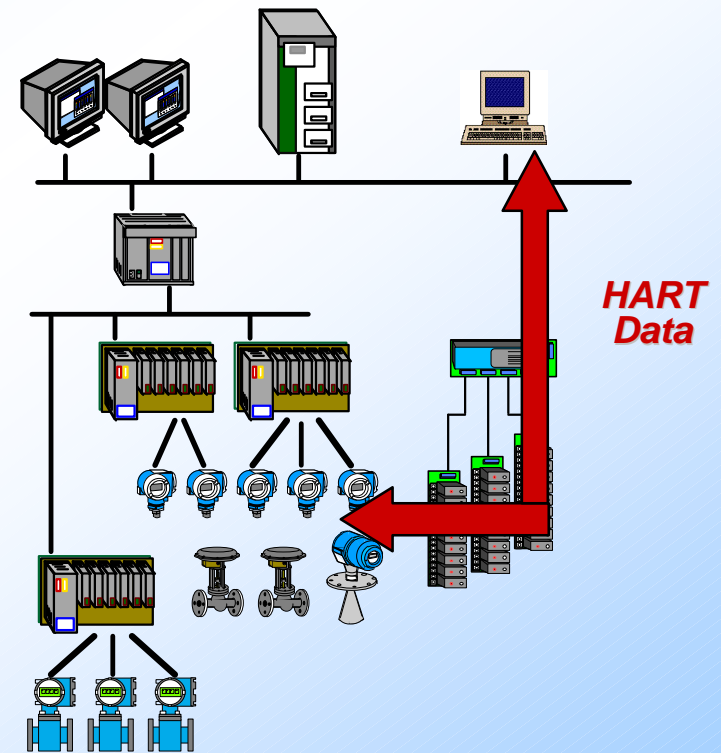
- Usually Uses "Multiplexers"
- Duplicates Existing Hardware and Wiring
- Maintenance Station Primary Recipient

## ■ HART Data Access

- Slow HART Communications
- Limited Access to HART Data
- Maintenance Station May Publish Data (e.g., using OPC)
  - » Operator Station
  - » Data Historian
- No HART Access in I/O System, Controller

## ■ Benefits

- Remote Diagnostics / Maintenance
- Lowers Maintenance Costs



# HART Pass-Through

## ■ 1st Generation System Support

- Communication not Continuous
- Usually Uses Dumb Multiplexed I/O
- Maintenance Station Primary Recipient

## ■ HART Data Access

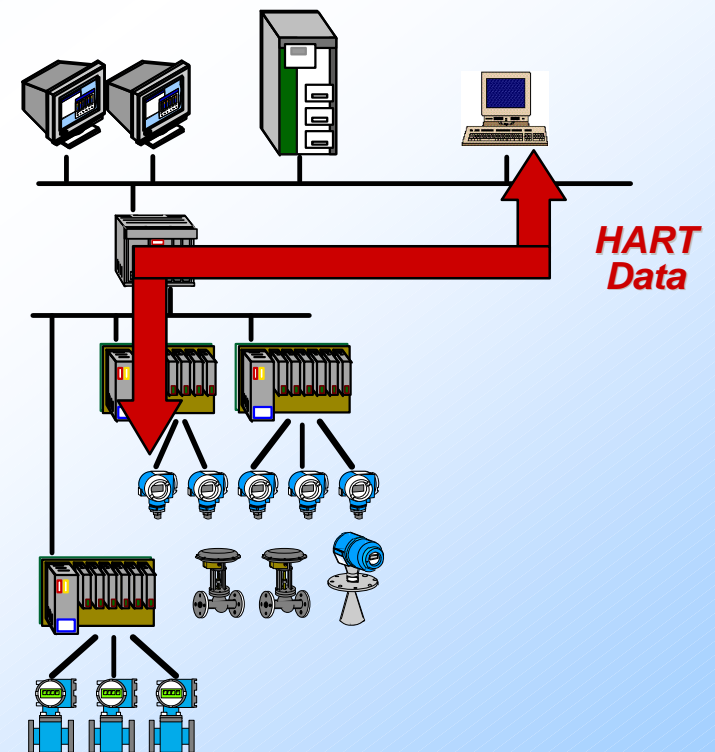
- Very Slow Communications
- Limited Access to HART Data
- Little Native HART Knowledge in I/O
- Controller HART Data Access Possible (Can be Difficult to Achieve)

## ■ 4-20mA Communications Not Secure

- I/O Knows 4-20mA Value  
Not the Maintenance Station

## ■ Benefits

- Remote Diagnostics / Maintenance
- Lowers Maintenance Costs
- Reduces Hardware and Wiring Duplication



# Systems with Integrated HARTAbility

## ■ Support True Full-Time HART Communications

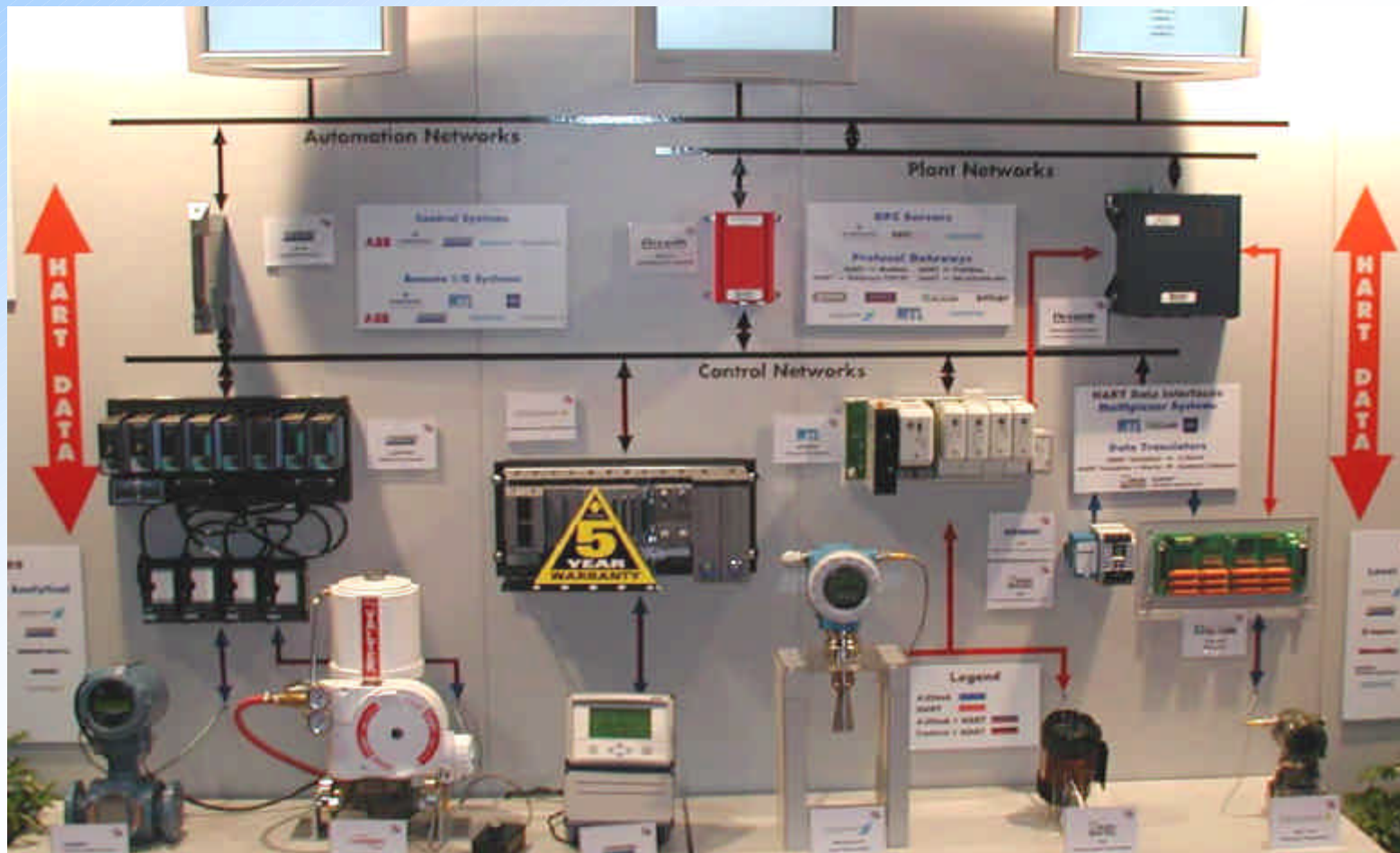
- Enhances Early Problem Detection - Reduces Unscheduled Downtime
- Lowers Maintenance Costs - Fewer Unnecessary Service Calls
- Validates Process Data - Improves Product Quality
- Improves System Integrity

## ■ These Systems Contain

- Smart One-One I/O Systems
  - » Continuous Validation of 4-20mA Communication
  - » Real-Time Access to Digital Secondary Variables - Exploit Your Multi-Variable Field Device Investment
  - » Simplified, Cost Effective I/O - One Channel per Multi-Variable Field Device
  - » Monitor HART Status - Enables Reporting by Exception
- HART Aware Controls
  - » Utilization of HART Digital Process Data and Data Quality
  - » Standard Templates to Simplify Access to HART Data and Status
  - » Full Access to All HART Data = Full Knowledge of the Process
- Operators Station with a Complete View into the Process

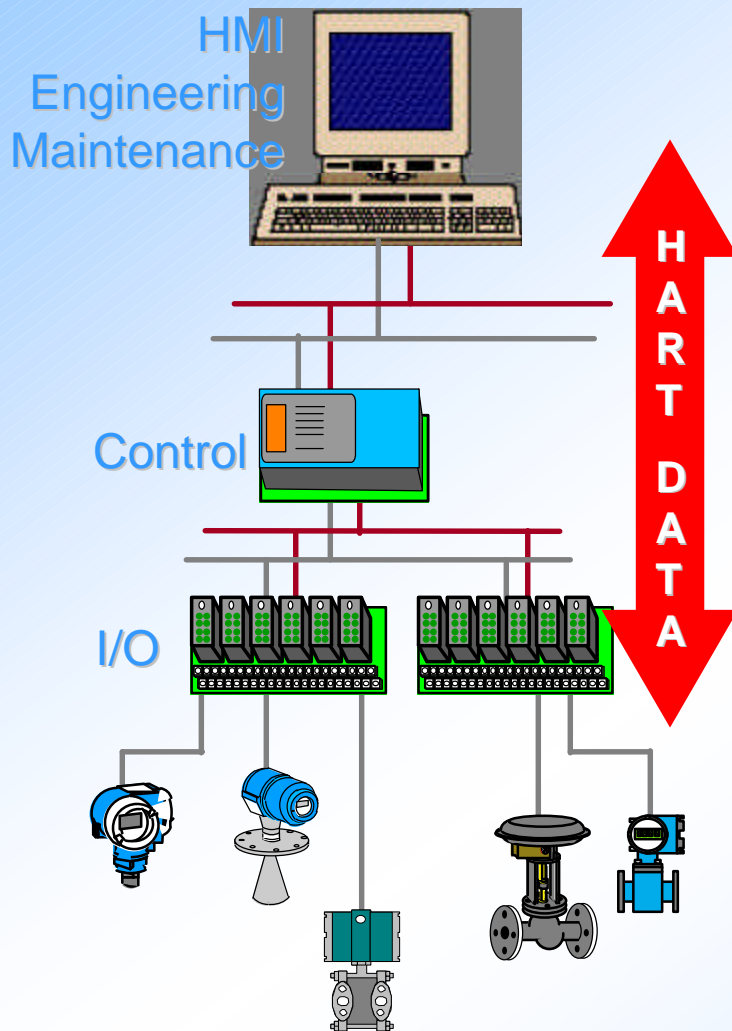


# Solutions for HART Integration





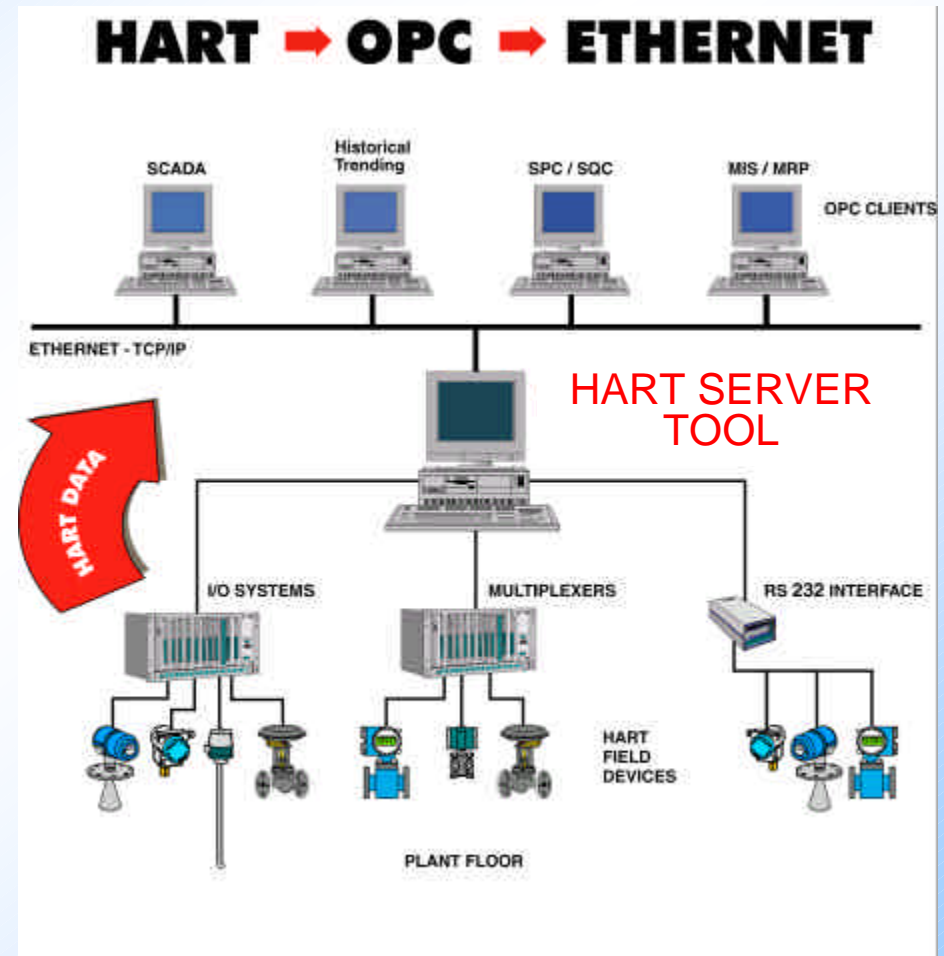
# HART System Integration



- **Cost-effective interface solutions support integration with plant control systems**
- **Many control systems have direct HART-capable I/O and support use of the data at all levels**
- **Third party products support integration with legacy systems**
  - **Multiplexers** - Some integral with Field Termination Assemblies
  - **Gateways** - HART to Ethernet, HART to Modbus, HART to Profibus, more...
  - **Single Device Interfaces** - convert digital process variables and device diagnostic alerts into 4-20mA signals and/or contact closures

# Integration with Plant Networks

- OPC Server provides easy access to HART device data anywhere on plant network
- Allows several applications to access data in a HART device at the same time
- Enables popular HMI and Trending packages to access data in HART devices
- Connect to one or thousands of devices using common HART I/O systems & interfaces
- HART Data on Your Desktop anywhere in the plant



# HART Integration Summary

## ■ Continuous Real Time Diagnostics

- Device Problems
- Loop Current Faults
- Device Needs Maintenance

## ■ Continuously Validate Integrity of Control Information

- Ensure accuracy of system data
- Verify Loop Current, PV and Range values in device match those of system
- Automatically detect any deviation between device and system

## ■ Unlock additional information in Multi-Variable devices

- Secondary Process Variables for operator display, trending, or control
- Better information to improve plant operation and manage assets



***High VALUE + LOW Risk***

# Unleash the Power

## ■ Pick What Benefits Make Sense For Your Plant

- Value Today with Little or No Integration (Just Using a Handheld)
- Benefits Grow as Your HART Integration Grows

## ■ Major Plant Overhaul Not Required

- HART Compatible with existing instrumentation systems and people
- Allows benefits to be achieved incrementally
- Use Your Field Devices Better, Don't Throw Them Away and Start Over

## ■ Migrate at Your Pace

- Focus on Key Process Units
- Strategically Enhance Your System
  - » Get More From the HART Equipment You Already Own
  - » Add Smart I/O, HART Aware Control, Asset Management Tools, More HART Field Devices
- Evolution Not Revolution

## ■ Low Risk, Cost Effective, Excellent ROI





# Take Action!

## ■ Learn More About HART

- Provide HART capability training for your staff
- Understand the Opportunities
  - » Which Capabilities Fit Your Plant Needs
  - » Which Tools Deliver those Capabilities

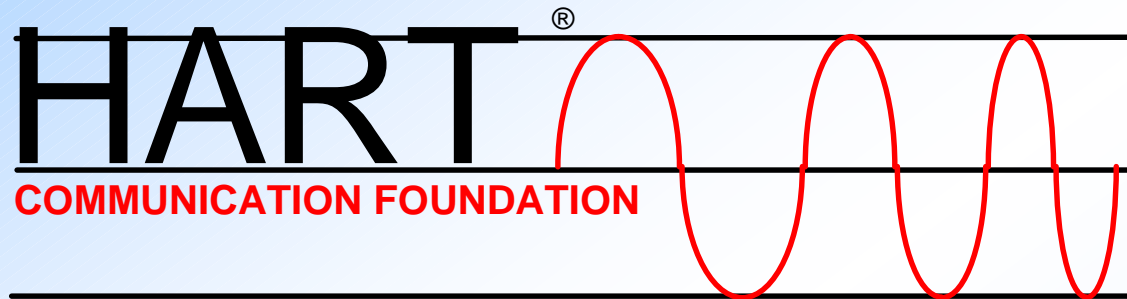
## ■ Ask Lots of Questions - Like

- What Conformance Class Level Is Its HARTability?
- Is The I/O Smart?
  - » Can it Validate and Secure the 4-20mA Communication?
  - » Is it only capable of Pass Through?
  - » Is it One-One or Multiplexed?
  - » How does it Support Multi-Variable Field Devices?
- Is the Control HART Aware?
  - » Does it Make it Easy to Use all HART Capabilities?
  - » Can it use the Secondary HART Digital Process Variables?
  - » Does it Understand the HART Status
  - » Can it Detect Configuration Changes
- Keep Asking Questions

## ■ Be Pragmatic and Start Evolving Your Systems



# Support for HART Technology



- Provide Worldwide Support for Application of the HART Communication Technology
- Technology Owner and Standards Setting Body for HART Communication
- Independent Non-Profit Organization - Funded by Membership and Training/Support service fees
- Any Company interested in Use of the HART Protocol should be a member





# Foundation Services

- Manage and control the HART Communication Protocol Standards
- Enhance the HART technology as necessary to support industry needs for Smart Instrumentation
- Provide Training Workshops, Newsletters, Web Site and other Services to Educate Industry on use of the HART Protocol
- Manage Library and distribution of Registered Device Descriptions for all HART devices



## The Bottom Line...

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**Most Users and Suppliers are not using  
the *full* value of HART**

**Communicate with your HART devices  
and...**

***Unleash the POWER!***

# Questions?

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***Thank You for Your Attention!***