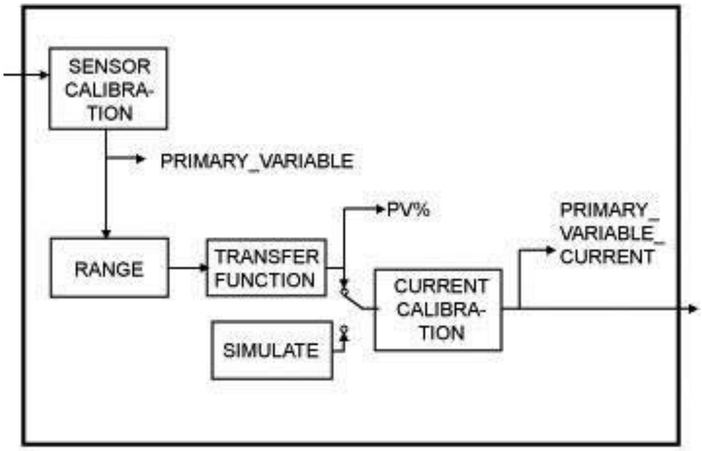

Figure 4–46 A HART Transmitter Block Diagram

- There is a wide range of HART-compatible devices in process measurement and control product categories including valve positioners; digital valve controllers; actuators (pneumatic and electric); and some 4-wire devices that include magnetic flowmeters, level devices, analyzers (liquid and gas), control devices (control systems, PLCs, multiplexers) and others.
- HART Protocol allows the simultaneous communication of the continuous 4–20 mA signal as well as a second digital communication path resting on top of the analog signal but not interfering. The digital information is communicated via the field proven Frequency Shift Key (FSK) technology that superimposes a digital signal on top of the analog signal.
- A Device Description (DD) is an optional element of the HART communication technology and is not required to communicate with a HART device. DDs are mostly used for device set-up and are not required for routine device communication.
- With HART, the analog 4–20 mA signals are there full time to address the needs of fast changing or critical process measurements. Data to support multivariable measurements, remote diagnostics, and device status can be accessed digitally while the analog signal is being used for control.
- Accessing the data in HART devices on a full-time routine basis increases the performance, integrity, and reliability of plant control and enterprise level systems. Getting digital data direct

from the device avoids the filtering that may occur in acquiring this information through intermediate systems. Process variables are provided in engineering units. Status indicators provide information on the quality of data and health of the device [Ref. 12].

4.36 HART SUMMARY

HART communication was developed as a hybrid system to bridge the link between the analog domain (4–20 mA) and a digital communication protocol that was yet to be developed. Although several standardization committees worked for many years to adopt a standard protocol for field communications, progress was made but such a standard was never established. The need for an all digital control network led to the formation of the Fieldbus FOUNDATION Organization, which developed the presently used standard for communication between digitally operated field instruments. With the adoption and use of FOUNDATION Fieldbus (FF), many predicted that the long awaited all digital system had at last arrived and HART applications would give way to FF. A survey in 2004 by the Automation Research Council (ARC), however, confirmed that HART adoption by users was actually expanding instead of declining as some predicted. Automation applications include multiple communication protocols to meet the diverse needs of both manufacturers and users. These protocols for the processing industries are largely HART and FF with Ethernet.

FOUNDATION Fieldbus

Networking was introduced into the nearly all analog world in the 1970s and was first utilized in direct digital control (DDC) systems between computer and I/O. Later, it was used in distributed control systems (DCS) and programmable logic controllers (PLC) to connect the controllers and operator consoles. In the 1980s, digital communications were used in field devices (digital transmitters). HART was developed as a hybrid communication system between the analog control instruments and field instruments over the 4–20 mA transmission system. True digital communication bus networking of field instruments began to gain wide acceptance in the 1990s. Many networks, including television, radio, telephones and industrial control systems, are now analog but the trend is definitely toward all digital communication systems.

Digital communications enable data to be transmitted serially between field devices and controllers, workstations and servers. A major advantage of such communications is that a great deal of information can be transmitted over a single cable instead of the two-wire twisted pairs required for each control loop with 4–20 mA. Also, digital communications carry not only the process and manipulated variables but operational information such as set point, mode, alarms, and tuning information. This has enabled distributed processing, diagnostics, configuration, transmitter calibration, valve configuration, and other functions of both field and control stations to be manipulated and coordinated from one single point or location.

FOUNDATION Fieldbus technology is an all-digital, serial, two-way communication system which interconnects field equipment such as sensors, actuators and controllers. It is a local area network (LAN) for instruments used in manufacturing and process automation with built-in capability to distribute the control applications across the network. FOUNDATION Fieldbus incorporates a field control system that can enable the control strategies to be distributed among the field devices. The use of function blocks enables control system strategies to be configured according to the needs of the users. Function blocks within the fieldbus devices perform the various functions required for process control. Because each function is different, the mix-and-match of the configurations of functions are different. A range of function blocks has been designed, each to address a different need, and all function blocks for process control applications have been developed. For example, the function blocks needed for a single loop control system are AI, AO, and PID.

With digital communications, there are many different methods of representing, encoding, and transmitting data. Each method is called a protocol. Manufacturers have devised many different protocols and products designed for one protocol are not compatible with those designed for another.

ISA's SP50 committee, which developed the 4–20 mA standard and others, has worked to define a standard protocol that all devices can follow. Such a standard protocol would make it possible for equipment from different manufacturers to interoperate and thus be able to communicate with each other. HART, FOUNDATION Fieldbus (FF), and Profibus are all based on the Open System Interconnection (OSI) reference model as defined in the ISO 7498 standard. While HART and FF are prominent in the process industries, Profibus is used for the faster applications found in automated manufacturing. The OSI model as applied to fieldbus technologies is shown in Figure 4–47. Notice that layers 3, 4, 5, and 6 are not used in FOUNDATION Fieldbus. The Fieldbus Foundation is an independent organization comprised of more than 100 instrument and control suppliers and which provides the specifications for the fieldbus communication stack and user. DD technology provides the interoperability between devices from different suppliers. To ensure this interoperability, conformance and interoperability testing software kits have been made available to the product developer. Conformance testing by FF ensures that fieldbus products conform to the communication stack and technology standards established by FF. All devices submitted to FF for interoperability testing must pass FF conformance testing. Only products that pass this testing can be approved by FF. A lack of conformance and interoperability testing does not prevent manufacturers from selling products with FF technology; some suppliers have sold FF compatible products that have not undergone the full range of testing from FF. Users will no doubt want to make certain that any equipment purchased for FF application has been certified to be in compliance.

Process-related networks include FOUNDATION Fieldbus, Profibus PA (application profile) and HART. As a category, all of these buses are referred to as "fieldbus" without the capital F. FF specifically represents FOUNDATION Fieldbus. All of these networks were designed for bus powered field instruments with predefined parameters and commands for asset management information such as identification, diagnostics, materials of construction and functions for calibration and commissioning. Generally, the networks used in automation and control are considered local area networks, usually a mile or so in diameter.

In these small networks however, there is still a need for different network characteristics, and FF is comprised of a two-tier control system hierarchy. In the field there are instruments such as transmitters and valve positioners with specific characteristics and needs. At the host level, workstations, linking devices, and controllers have other requirements.

For this discussion, the two-tier network consists of the field network, connecting the field instruments, and Ethernet, connecting the host devices. Figure 4–48 shows the linking device (H1 card) for the two networks. The fieldbus has two wires that are used for both communication and power to supply the bus. Bus power supply voltage is from 9–32 VDC, which is the voltage range required to supply the fieldbus instru-

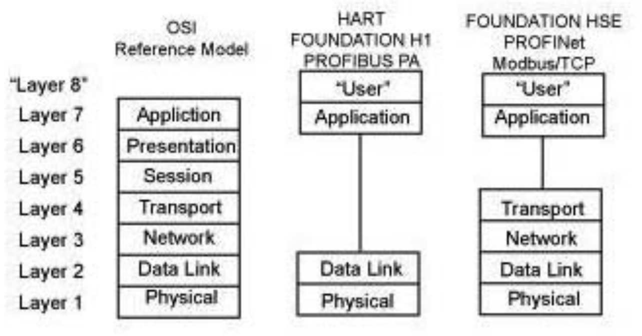

Figure 4–47 Open System Interconnection Reference Model

Figure 4–48 A Two-Tiered Automation Network Architecture Showing the Linking Device (*Courtesy of ISA*)

ments. The instruments are connected to the two-wire bus in parallel and each field device connected forms a spur. The spurs can be connected to the trunk by any appropriate connecting method but it is helpful to use specially designed connection terminals for ease in connecting and disconnecting field instruments. Individual instruments

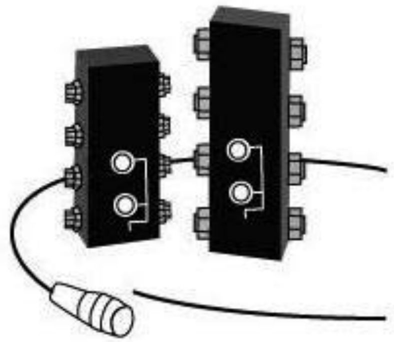

Figure 4–49 Junction Box (*Courtesy of ISA*)

can be disconnected from the trunk without disrupting the operation of other instruments on the bus. Figure 4–49 shows a junction box for connecting instruments to the bus.

The components, trunk, and spurs comprise a segment. A maximum of 32 devices can be on one segment if the instruments are separately powered. Most devices are bus powered and because of the voltage drop along the bus caused by the impedance of the devices creating a load, the maximum number of devices for bus-powered applications is 16.

Each segment must have two terminators, usually one at each end. The terminator is made of a 100 ohm resistor and a 1 microfarad capacitor. It does not communicate, but prevents signal communication errors caused by reflection and converts the current on the network to voltage, which is the receiving signal. Terminators, like other bus devices, are not polarity-sensitive.

The bus power supply must have an output impedance in accordance with the Digital Data Communication for Measurement and Control standard series IEC 61158. A power conditioner, usually in the power supply, matches impedance to the bus to prevent the signal from being shorted by the normally near-zero ohms impedance of the power supply. Figure 4–50 shows the application of a conventional power supply with an internal power conditioner and an added terminator. The interface unit is the H1 card.

Devices can be connected in two basic topologies, bus and tree. (Figures 4–51 and 4–52). For bus topology, the main cable, called the trunk, runs from the marshalling panel (usually near the control

Figure 4–50 Application of a Power Supply with an Internal Power Conditioner and an Added Terminator (*Courtesy of ISA*)

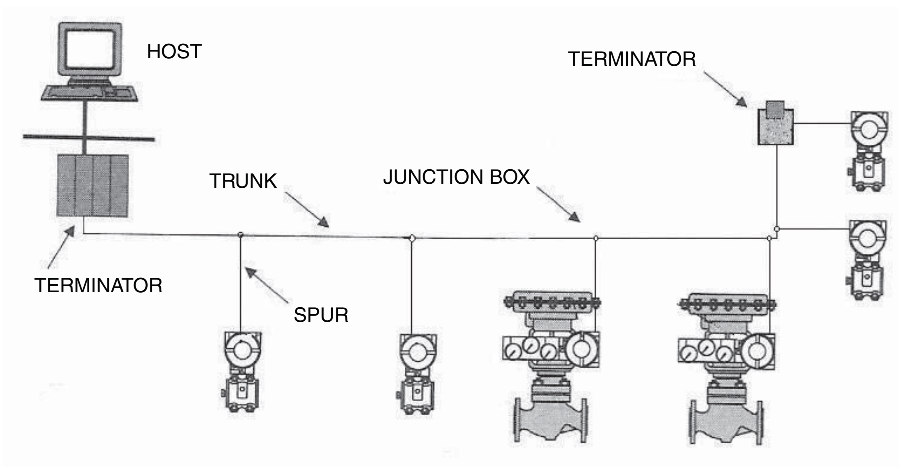

Figure 4–51 Bus Topology (*Courtesy of ISA*)

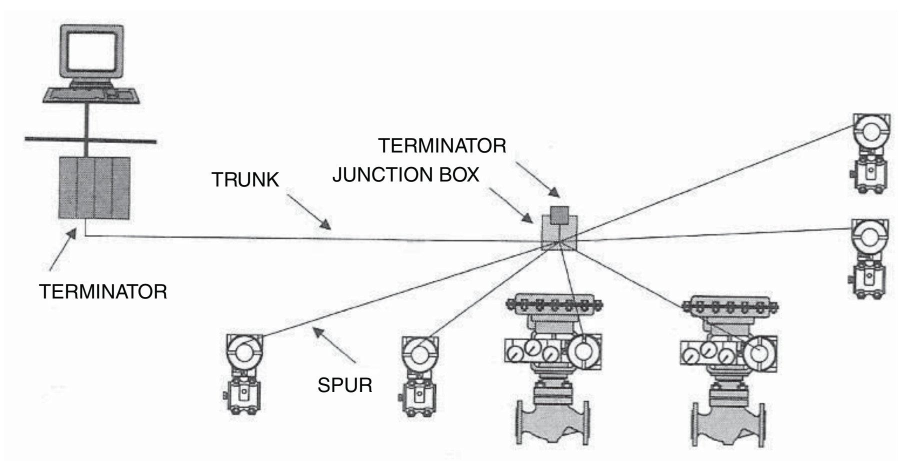

Figure 4–52 Tree Topology (*Courtesy of ISA*)

room) into the field to the last device, servicing each device along the way. Field devices are connected to the trunk by shorter wires called spurs. For tree topology, the trunk runs into the field, where it branches out into the individual devices from a single junction box. This topology minimizes the number of connections but the cable length of the trunk is longer, especially when the field instruments are not close together. Tree topology is more common in upgrades in older plants.

The IEC 61158-2 standard does not specify the type of cable to be used for the trunk and spur. Because of cable resistance, the fieldbus signal is attenuated as it travels down the trunk until it becomes too low to power the instruments. Normal current on the bus is 12 mA. The expected total length for four types of cable is listed in Table 4–3. Types A and B are recommended for new installations and type B is particularly suited for home runs from the field junction box to the marshalling panel. FF cable requirements were specifically designed so that wire in existing 4–20 mA applications can be used when upgrading to fieldbus.

For FOUNDATION Fieldbus devices, the mode address assignment is automatically handled by the linking device or another interface unit so the field device can be connected directly to the network. This is done after the device support files have been loaded or installed in a dedicated folder for support files, with subfolders for manufacturer and device type. The support files are normally shipped with the device or otherwise obtained from the manufacturer. Once the field device is installed and connected to the network, it will be detected and displayed on a live list with all the other devices on the same network (Figure 4–53). Should the device not appear on the live list, it may be connected to the wrong network, have a faulty wire or connection, not be connected properly, or be a faulty device. Once the device is detected, and to ensure that it is the correct device in the correct location, it is good practice to disconnect the device, see if it disappears from the live list, and connect it again to see if the correct tag reappears on the live list.

Once the device is identified, it will be assigned a mode address noted for temporary use until the configuration is continued for assignment in a permanent address location.

Each FOUNDATION Fieldbus device has a unique 32-character device identifier (Device ID) that is like a hardware address that is one-of-a-

Table 4–3 Typical Cable Types and Range

Pair	Shield	Twisted	Size	Length	Type
Single	Yes	Yes	0.8 mm^2 (AWG 18)	1,900 m (6,200 ft.)	A
Multi	Yes	Yes	0.32 mm^2 (AWG 22)	1,200 m (3,900 ft.)	B
Multi	No	Yes	0.13 mm^2 (AWG 26)	400 m (1,300 ft.)	C
Multi	Yes	No	1.25 mm_2 (AWG 16)	200 m (650 ft.)	D

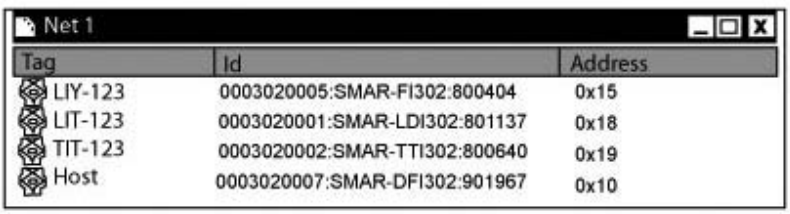

Figure 4–53 Live List

kind and is used to distinguish a particular device from all others. This address is set in the circuit board by the manufacturer and is permanent. During configuration, a particular device is set in a control or measurement strategy associated with its configuration tag and device ID. This concept is known as OLE—Object, Linking, and Embedding—for process control. Once all devices are associated with their respective device tags, the configuration can be downloaded for the entire network or individually. Some manufacturers preconfigure device tags so they will automatically be matched to the configuration.

Parameters are set in the resource and transducer blocks. These blocks have several characteristics in common with the function blocks that are used to build the control strategy. Each device must be configured with one resource block. All input and output devices can be configured with one resource block and they can be configured with at least one transducer block, one for each measurement or actuation. Transducer blocks act as an interface between physical I/O hardware and function blocks. The resource block contains information about the device as a whole. Transducer and resource blocks have no input or output parameters and cannot be linked. Each block should be identified by a block tag (FB_TAG); these tags should be the same name as the device tags on the P & ID (Process and Instrumentation Diagram).

During the configuration of FOUNDATION Fieldbus devices, the range is normally set. There is a difference between range setting and calibration. Calibration principles were given in Chapter 2. Recall that calibration required a known value of the process variable, or a simulated value, to be applied to the input of the instrument under test. The value and the corresponding output are then measured with a test instrument. Corresponding values of input and output, at least three and usually five, are established at various points along the measurement range of the instrument. From this, a data table and calibration plot are made to confirm the instrument's accuracy. This procedure formerly required the instrument under test to be removed from service and transported to a calibration laboratory. This calibration procedure also required accurate test instruments, three to five times as accurate as the IUT (instrument under test), and a calibration apparatus for the simulated inputs. This was needed to correct the sensor reading to match the applied quantity and to check linearity. As in HART calibration, setting the range with FF devices means establishing the values for zero percent output and one hundred percent output or the lower range value (LRV) and the upper range value (URV). Test instruments and a calibration apparatus are not needed.

For both HART and FOUNDATION Fieldbus, a technician can set the range remotely without applying any inputs, but by definition calibration means that a known input from a standard must be applied; a corresponding output is compared and matched to the input.

Damping can be used to filter out measurement signal noise by configuring a filter time constant in seconds. It should be noted, however, that when signal noise is a result of an equipment malfunction, filtering simply masks the problem and can hide actual process responses.

Digital pressure transmitters contain pressure transducer blocks that indicate the primary value type and parameter. This specifies whether the sensor is for differential pressure, gage pressure, or absolute pressure. The sensor type parameter also indicates which technology is used in the pressure sensor: strain gage (resistive or resonant mode), capacitance, or another technology. The primary value parameter is always the measured pressure that is passed on to the analog input (AI) function block by way of the hardware channel. The AI block can convert the pressure measurement into flow, level or some other inferred measurement [Ref. 13].