

Media Info

Channels

News

Web Exclusives

Directories

Tutorials

Products

CE Issues

CE Europe

Trade Shows & Events

Other Resources

Site Search/ Site Map

Home

October, 1998 Control Engineering

## 4-20 mA Transmitters Alive and Kicking

*Fieldbus is everyone's hot topic, but 4-20 mA measurements are still the mainstay.*

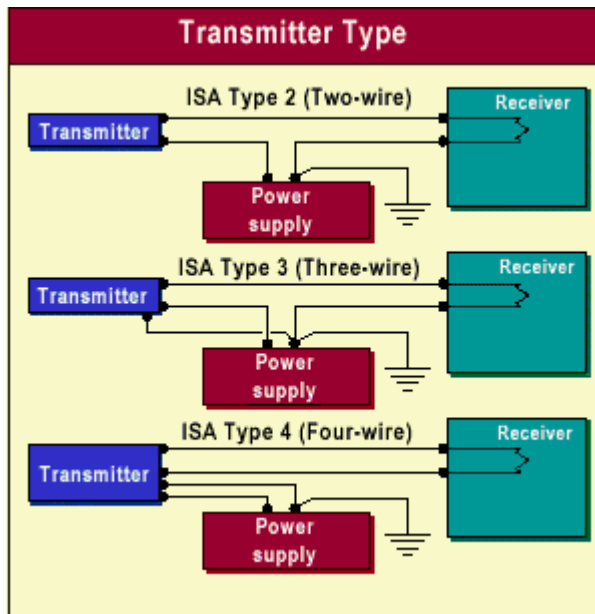
Dave Harrold, CONTROL ENGINEERING

Sidebar

[List of 4-20 mA Terms](#)

Because they've been around so long, everyone already knows all there is to know about 4-20 mA transmitters and how to install them. But, if so much is known about selecting and installing 4-20 mA transmitters, why do the same questions keep coming up? Questions like:

- "What is the difference between two-, three- and four-wire transmitters?"
- "Are there issues when mixing two- and four-wire transmitters in the same control system?"
- "When and why would line isolators be necessary?"
- "When and why would intrinsic safety barriers be used?"
- "What happens if there are isolators, intrinsic barriers, and HART transmitters all in the same installation?"
- And my personal favorite, "Why doesn't the process variable ever reach 100%?"



ISA S50.01 categorizes transmitters into two-wire, three-wire, or four-wire types.

### Transmitter classifications

Understanding differences between two-, three- and four-wire devices will help clear up several of

the questions.

ANSI/ISA-S50.1-1982 (R-1992) standard *Compatibility of Analog Signals for Electronic Industrial Process Instruments* established transmitter type classifications as being the number of wires (2, 3, or 4) required to provide power and output circuits (see Transmitter Type). (Shield and input circuit wiring are excluded.)

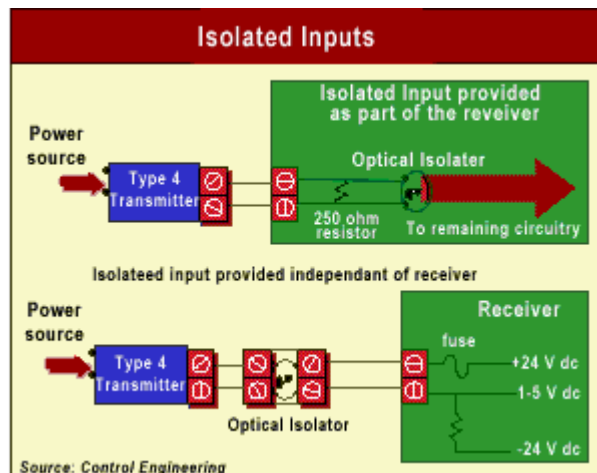
Four-wire (Type 4) transmitters use two wires to power the transmitter and two wires to provide the 4-20 mA output signal and are usually not used for conventional pressure, temperature, or level measurements.

For example, magnetic flowmeters often include a sensing element and separate enclosure containing a power supply and other electronic components requiring a separate power source. The electronics enclosure is mounted near the sensor because of distance restrictions. This results in a four-wire installation where two wires provide electrical power, and two wires transmit the output signal to a receiving device, such as a distributed control system, a programmable control system, a data acquisition system, a recorder, or an indicator.

Plant topologies frequently place transmitters at significant distances from the receiver to which they are connected. When four-wire transmitters are used, the power source for the transmitter can be different than the power source for the receiving device. Unless careful maintenance is taken to isolate between electrical systems, ground loops are formed, introducing unsafe conditions at worst and electrical "noise" at a minimum. (Like the "hum" you hear coming from your stereo speakers only when the sump pump kicks on.)

Electrical ground loops can occur in two ways: When components in the same system receive power from different sources with different grounds, or when the ground potential between two connected pieces of equipment is not identical. A potential difference in the grounds causes a current flow in the interconnecting wiring. The receiver treats all incoming current flow the same producing an incorrect reading.

Preventing ground loops in four-wire transmitter circuits can be as simple as specifying isolated input channels for the receiving device (see Isolated Inputs). Receiver isolated inputs may be physically different input cards and terminations, or use of specific terminal combinations. When isolated input channels are not available for the receiver, separate line isolators should be used.



**Transmitter and receiver isolation is necessary when different power sources are involved to prevent the dreaded ground loop.**

Regardless of how achieved, it's good practice to provide electrical isolation between four-wire transmitters and their receiver. ISA's S50.01 standard states, "In no event should transmitters with grounded outputs be connected to grounded receivers. They require an isolator in the loop or floating receiver system."

Two-wire (Type 2) transmitters contain circuitry to vary the amount of current flow but require an external source of excitation power.

Three-wire (Type 3) transmitters require the same design and installation considerations as two-wire transmitters.

### **Intrinsic safety**

Intrinsic safety (IS) involves designing electronic circuits in such a way that the circuit cannot release sufficient energy to ignite hazardous materials in the surrounding atmosphere under any combination of component failure, design flaw, or operating and maintenance faults.

Intrinsically safe installations can be achieved through inherent system design, by selecting individually approved devices (also called entity method), or by using barriers.

Inherently designed installations require every device in the system to be individually designed to constrain field energy levels, regardless of faults or other operating conditions. When properly implemented, this approach provides an extremely high degree of protection. However, open control systems introduce system approval challenges beyond what most process control engineers are willing to accept.

Entity approval methods allow barriers and field devices to be tested and approved individually. Using the safety parameters assigned to each device, users can select a mixture of IS approved equipment from different manufacturers without need for additional IS approvals.

Use of barriers to achieve intrinsic safety is the most common solution and involves placement of safety barriers in signal wiring between safe and hazardous areas. Barriers are available using either active (galvanically isolated) or passive designs (see Intrinsic Safety Barriers). Active barriers combine transformers and optoisolators, or relays to form an isolation safety barrier. Passive barriers use resistors and diodes to form the safety barrier.

Intrinsic barriers are designed to limit the amount of current and voltage passing into the hazardous area below the ignition point of the flammable or explosive atmosphere. Depending on several criteria, including barrier design, power source, and area classification, it may be necessary to install a safety barrier in both wires. However, most dc circuits can be safely grounded at one point without affecting the power supply's operation. If one of the wires can be attached to a designated IS ground, the need to install a barrier on that wire is eliminated. Designating an IS ground requires special considerations, including prevention of introducing ground loops into the circuit.

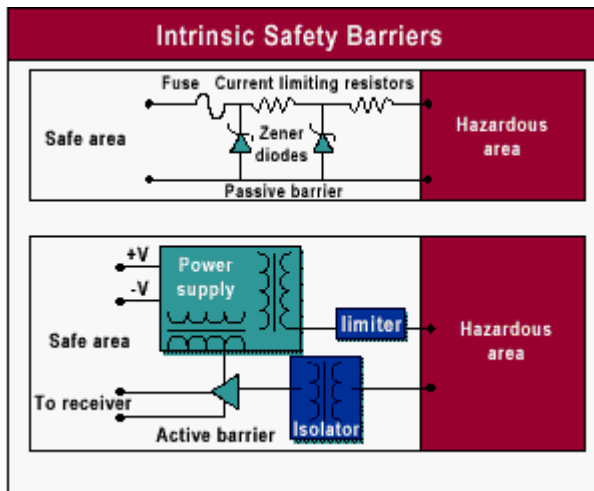
Using approved intrinsically safe techniques to protect hazardous atmospheres remains optional in many industries and world areas; explosion proofing is the alternative.

Benefits of intrinsically safe installations include:

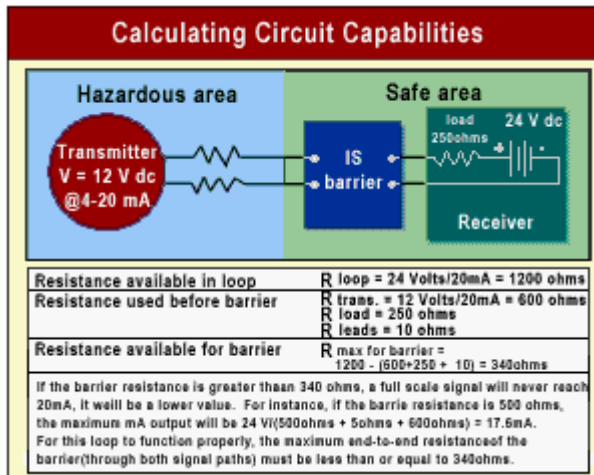
- All devices are accessible--no testing for gas, or explosion-proof housings to open;
- Personnel safety is assured because of low-voltage operation; and
- Standard wiring techniques in open cable trays or light conduit save on initial installation material and labor costs.

### **HART and 4-20 mA**

HART's (Highway Addressable Remote Transducer) protocol makes use of the Bell 202 frequency shift keying (FSK) standard to superimpose low-level digital signals on the 4-20 mA circuit enabling more information than just the process variable to communicate between transmitters and receivers.



Intrinsic safety barriers use passive or active components to limit voltage and current into hazardous areas. Passive barriers frequently use redundant components for added protection.



Determining if a 4-20 mA circuit has sufficient voltage to reach 100% readings is a simple, but important exercise to ensure circuit integrity.

HART's protocol *command set* is organized into three groups. Universal commands are implemented by all HART devices and provide interoperability across products from different manufacturers. Universal commands include: manufacturer and device type; primary variable and units; current output and percent of range; four predefined dynamic variables; eight-character tag, 16 character descriptor, and date; and several more.

HART's *common-practice command set* is used in many HART field devices, but not all, and include such functions as: writable transmitter ranges; ability to set zero and span; perform self-test; and more. *Device-specific commands* are the third set and are unique to a particular field device. Functions of the device-specific command set include: start, stop, or clear totalizer; select primary variable; PID setpoint, and tuning parameter manipulation.

Using HART transmitters in intrinsically safe installations requires special isolated (active) intrinsic barriers capable of passing the digital FSK data while maintaining safety on the 4-20 mA circuit.

### Driving the circuit

No steering wheel is provided, but the need for power is critical in achieving robust 4-20 mA installations. A symptom of an under-powered 4-20 mA circuit is the inability of the transmitter to produce a 100% output reading. Depending on how the variable is used, inability for the receiver to obtain 100% transmitter values can create anything from a mere nuisance to an unsafe

condition.

Understanding the electrical response of different transmitters is key in designing, installing, and maintaining 4-20 mA loops with sufficient power to operate through the entire variable range.

Establishing transmitter interoperability was a major goal of ISA's S50.01 standards committee. Besides the transmitter type classifications discussed earlier, S50.01 established class suffixes (H, L, and U) to identify a transmitters load resistance capability with respect to its power supply voltages (see table). Combining type and class classifications, a Type-2L transmitter from one manufacturer can replace one from another manufacturer without changing other devices in the circuit.

<b>Transmitter Class Suffix Classifications</b>			
	<b>H</b>	<b>L</b>	<b>U</b>
Load Resistance (ohms)	300	800	300 to 800
Minimum supply voltage	23 V dc	32.7 V d	23 to 32.7 V dc

*Source: ANSI/ISA-S50.01-1982 (R-1992)*

To avoid installing an underpowered 4-20 mA circuit, and later the question "Why does my process variable never reach 100%?", the voltage drop contribution of each device must be considered (see Figure 4). Likewise, any new devices added to the circuit, such as replacing a blind transmitter with one that includes a local readout, deserve reviews to ensure circuit integrity.

Analog (4-20 mA) transmitters have been around a long time, and most are operating just fine. Fieldbus technologies promise unprecedented information about what is happening within processes, but it's likely to take at least two decades before digital fieldbus completely replaces 4-20 mA. In the meantime, transmitters providing critical measurements deserve periodic reviews of power, grounding, isolation, and protection elements that may reveal sources of unwanted measurement gremlins. h

*For more information, visit ISA web site at [www.isa.org/standards/index.html](http://www.isa.org/standards/index.html).*

*For more information on ANSI standards visit [www.ansi.org/public/std-info.html](http://www.ansi.org/public/std-info.html).*

[Top](#)

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## List of 4-20 mA Terms

Type 2 transmitters require two wires to simultaneously carry excitation power and the output signal.

Type 3 transmitters require three wires to simultaneously carry excitation power and the output signal.

Type 4 transmitters require four wires. Two wires for excitation power, and two wires for the output signal.

Two-wire transmitters - See Type 2.

Three-wire transmitters - See Type 3.

Four-wire transmitters - See Type 4.

Single-ended transmitters - See Type 2 or Type 3.

Self-powered transmitters - See Type 4.

Nonisolated transmitters are type 2 or type 3 used in an ungrounded circuit.

Power isolated transmitters are type 4 used in an ungrounded circuit.

Input-isolated transmitters are type 2 or type 3 used in a grounded circuit.

Fully isolated transmitters are type 4 used in a grounded circuit.

Dropping resistors are precision resistors, typically 250 ohms  $\pm 0.25$  ohms with a temperature coefficient of not more than 0.01%/8C, used to convert 4-20 mA signals to 1-5 V dc signals.

Range resistors - See dropping resistors.

[Top](#)

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*Control Engineering - October 1998*