The long and short of connecting sensors to control rooms

Temperature sensors, more than most other types of instrumentation, can require specialized cabling and treatment to provide accurate data.

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The choices made to get temperature measurements to the control room can have a profound impact on plant operation and costs. Temperature measurement can be found in control, monitoring, or logging situations, and quite often temperature is the most commonly measured variable in a plant. Every application has its own unique requirements for accuracy, reliability, and compatible system architecture. Matching these requirements with the right connectivity choice will ensure that the temperature measurement will provide the right performance for the right cost.

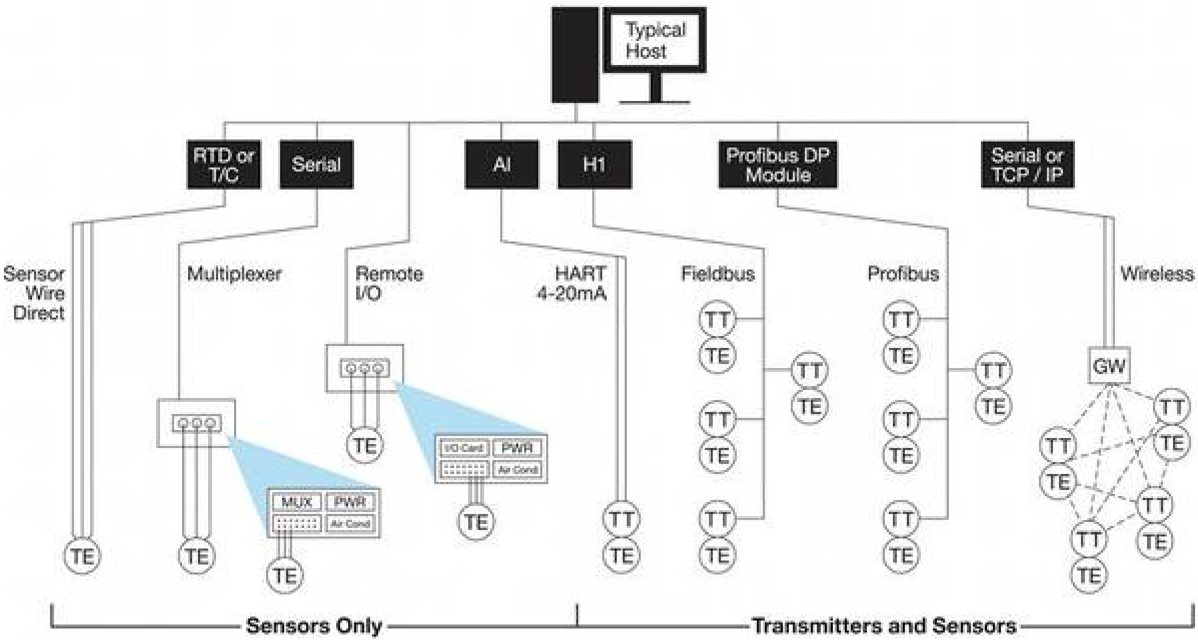
The ultimate objective is to get the temperature measurement to the control room with the accuracy, repeatability, and stability required for the application. In addition, the solution should offer ease of maintenance and the lowest practical cost of ownership. The design engineer must consider a number of technology, performance, and cost of ownership issues to make a proper decision.

As you begin evaluating an application, consider these questions:

- Are the measurements made with an RTD (resistance temperature detector) or TC (thermocouple)?
- How far are the measurement points (sensor locations) from the system connection?
- How are the connections made at each end?
- Are there junction boxes, conduits, or wire-ways?
- How and where is the raw sensor signal converted to a useable measurement value?
- Will using a transmitter help? If so, what kind of transmitter?
- Where could a transmitter be mounted?
- Is a wireless transmitter an option?
- Will this be strictly analog, or is a digital device-level network (fieldbus) used in the plant? If so, which one?

Connection options

There are several options to consider in choosing a reliable method to get the signal from the field sensor to the control system in a way that delivers the performance levels required by the application. Figure 1 illustrates the most common choices.



Direct wiring – Connect field sensors directly to input card racks within control room systems. The signal is conditioned or converted into an analog signal or digital value representing the temperature measurement for use in that system.

Remote I/O – I/O cards, racks, and power supplies are positioned into field marshaling cabinets that are connected to the control system via a digital link. The same attributes as direct wiring apply, but the sensor wiring runs are shorter.

Multiplexors – Typically using either serial RS232C or RS485 communications or Ethernet, multiplexers communicate with the control system. The communications can be any of a number of host protocols such as Modbus, OPC, Profibus, or other proprietary protocol. While generally reliable, this is a dated approach that has seen a decline in use.

Locally mounted transmitters – A transmitter is usually located in a connection head or enclosure mounted integrally with the sensor or in very close proximity. The most basic is a simple 4-20 mA output version with limited options and features. HART-enabled transmitters, which are the most common, provide a high-performance and cost-effective option for most applications. Fieldbus architectures use either Foundation fieldbus or Profibus, allowing multiple transmitters to share a common two-wire signal cable to the control room. Adoption of either of these fieldbus architectures is usually a management decision that applies to the entire plant facility or to a unit operation. Wireless is a rapidly growing technology with WirelessHART (IEC62591) and ISA100.11a (IEC62734) growing in numbers of deployments. Wireless transmitters can provide the same process variable information and diagnostic capabilities as wired versions.

Critical factors

Technology	Pros and Cons
Wire Sensors Directly to DCS	• High Wiring and Infrastructure Cost • Prone to Interference • High Maintenance • Limited Feature Functionality and Performance vs. Transmitter
Multiplexors	• Dated Technology • Slow Updates • Reliability Issues • Limited Accuracy and Performance Specifications • Area Certification and Environmental Limitations • Limited Parts, Service
Control System Remote I/O Racks	• Good Basic Capability • Proprietary Infrastructure • Limited Feature Functionality and Performance vs. Transmitter • Area Certification and Environmental Limitations
Transmitters and Sensors	• Highest Accuracy • Excellent Noise Immunity • Lowest Cost of Ownership • Wide Choice of Measurement Enhancement Features
Wireless Transmitter and Sensors	• Transmitter Accuracy • Low Cost of Installation • Fast to Implement

There are pros and cons to every technology, as shown in Figure 2. You should look for the solution that best matches your needs with the best cost-to-performance ratio.

Direct wiring using long sensor cables has to transmit low-level sensor signals that are very susceptible to interference. This electrical interference can come from sources such as pumps, motors, variable frequency drives (VFDs), and radios as well as sources of electrostatic discharge (welders and lightning) and other electrical transients. There is the potential for very large errors to be induced on the low-level sensor signals, and the longer the sensor lead wires, the greater the risk. Direct wiring may provide an adequate installation if the wire run distances are short and there is good separation and protection from interference sources.

Remote I/O cabinets may be cost effective for high-density measurement locations and where adequate protection from interference can be provided. Remote I/O requires an operating power source, which typically needs redundancy or an uninterruptible power supply for critical applications. An installation may also require environmental protection. Situations where a large number of measurement points are centrally located may allow for relatively short wire runs, but the sensor wire length may still be an issue for noise susceptibility and potentially significant errors.

The best and most common alternative is to use a transmitter, either analog or fieldbus, that is designed to reject common mode and normal mode interference, as well as provide a high degree of immunity to electromagnetic interference (EMI), electrostatic discharge (ESD), and radio frequency interference (RFI). Where possible and practical, transmitters should be mounted close to the measurement point to minimize any potential noise pickup by the sensor leads. This is especially important for low-level TC signals, which are especially susceptible to noise. Such transmitters may be simple 4-20 mA analog or HART enabled. Fieldbus transmitters have the same characteristics with all-digital architecture. The use of transmitters is sometimes thought to be expensive, but when the cabling and lifecycle maintenance costs are taken into consideration, this balance shifts.

The wireless transmitter option may prove to be cost effective for many applications, particularly where it is difficult or expensive to install traditional instrument infrastructure. A highly robust wireless system, as is available today, is achieved by proper network design. This approach is suitable for just a few measurements, or a system can be designed for an entire process unit operation.

Transmitters vs. direct wiring

Consideration of the high-cost of installation of direct wired systems and their high cost of ownership including maintenance and performance issues strongly suggests that using a transmitter approach has a clear advantage for most applications.

- Specifying a single temperature transmitter, sensor, and thermowell assembly to meet a specific performance goal simplifies purchasing and places responsibility on a single vendor.
- Transmitters can provide higher accuracy performance, often reducing the accuracy percentage by half.
- An individual sensor type can be changed from TC to RTD or to a different type of TC or RTD and the same transmitter can normally be reconfigured easily to the new sensor type. The output cable and the DCS input card stay the same. For direct-wired systems, the extension cable would likely need to be changed as well as the DCS input card.
- The standard two-wire copper wiring used with transmitters is far less expensive than the TC extension wire or four-wire RTD extension cable used with direct wiring.
- Higher performance is assured since a transmitter and sensor assembly may be calibrated as a system for optimal accuracy. This cannot be done with a direct-wired system and sensor. Extraordinary performance can be achieved by using the sensor-transmitter matching procedure inherent in high-end transmitters. While I/O subsystems (DCS or PLC input cards) have reasonable specifications, they are no match for the performance of today’s quality temperature transmitters.
- A transmitter facilitates using all copper wiring in the field, eliminating the potential for wiring installation errors that come from using different types of TC extension wire.
- A transmitter’s ability to work with multiple sensor types means that a user can often buy all its transmitters from the same manufacturer and likely even the same model, which minimizes spares.
- A 4-20 mA signal or digital fieldbus data from a transmitter is far less susceptible to EMI, ESD, and RFI than the low-level signals from a sensor. Some transmitters also offer intelligent filtering options to protect data integrity. Such software may not even be available in the control system host.
- Safety-related applications are by far best done in a transmitter-equipped system. In an SIS (safety instrumented system), an error in excess of 2% is considered an undiagnosed failure.
- Some transmitters offer an option that supports local display in the field, either as a built-in readout or mounted externally. This can be a major advantage when troubleshooting or in situations where operators are routinely in the area.
- Troubleshooting and maintenance time can be reduced by using the extensive transmitter diagnostics that are either not available or very limited in DCS input cards.
- A single type of high-level input card is required for the control system instead of a mixture of high-level and more expensive low-level cards, reducing inventory.
- Copper wire typically lasts for the life of the plant, eliminating the need to periodically replace degraded TC extension wire.

Good design yields cost-effective performance

When creating your instrumentation and networking design, always consider overall cost of ownership and not just purchase cost. Poor performance, higher maintenance costs, or more frequent replacement associated with low-cost products or deficient designs most often tilt the cost of ownership scale strongly in favor of a design using high-quality components.

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Key concepts:

- Temperature sensors have more options for connecting them to a control system than most other types of instruments.
- Various connection strategies have different trade-offs for durability and accuracy.
- Using a transmitter at the sensor can eliminate many of the headaches that can go with other sensor wiring methods.

Source:

http://www.controleng.com/single-article/the-long-and-short-of-connecting-sensors-to-control-rooms/ffd0f2e3742217009e97ad9de701b21e.html