What is a temperature transmitter?

Why use a transmitter?

Transmitter selection
- Ambient conditions
- Accuracy
- Location
- Indicators
- Options
- Communication types
- Wireless

Installation
- Protection from EMI/RFI
- Ambient temperature limits
- Rail mount vs. head mount

Calibration
- Matched calibration

Specifications
- Accuracy and other performance characteristics

Troubleshooting

Transmitters and indicators turned out to be a bigger topic than I thought when I began preparation for this presentation. What follows is information on the topics on which I get the most questions.

An electronic device that converts the input from an RTD, thermocouple, or other temperature measuring device to a current output.

- Analog
  - Converts a temperature measurement from an RTD or thermocouple to an analog value which is typically 4 - 20 mA of electrical current. Uses potentiometers to adjust output.

- Smart
  - A smart or intelligent transmitter is an analog or digital device combined with a processing unit and a communication interface.
  - Software or a communicator is used to calibrate and set functions.
**Terminology**

- **Zero**
  - Temperature setting for 4 mA output level
- **Span**
  - Temperature setting for 20 mA output level
- **Digital**
  - Electronic circuits representing signals by discrete bands of analog levels, rather than by a continuous range.
  - One advantage of digital vs. analog circuits is that signals represented digitally can be transmitted without degradation due to noise.
- **Analog**
  - A signal that contains information using non-quantized variations in frequency and amplitude.
- **Potentiometer (pot)**
  - Variable resistor

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**Analog Transmitter**

Calibrated using an ammeter, power supply, and screw driver

For some applications, simple is better. Measurement loops are easily fine tuned by turning the potentiometer screw.

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**Smart Transmitter**

Available in sizes and capabilities to suit every application
Programmed with PC, communicator or central control system

From a miniature head mounted device with minimal “extras” to a large head mounted transmitter with all the bells and whistles smart transmitters are designed to accommodate any temperature measurement requirement. Programming is accomplished by a software package and interface device, a handheld communicator, or remotely through a central control system.
Why Use a Transmitter?

Improve measurement accuracy

- Avoid lead wire error
- Transmitter output is more accurate than most direct input cards on controllers
- Linearize the non-linear sensor measurement
- Delay measurement – useful for environmental storage chambers

More robust signal over long distances

Local indication of temperature

Help protect measurement from electrical interference

- Sensor leads act like an antenna for RFI/EMI. Transmitter circuitry is designed to filter this noise. Mount transmitter as close as possible to the sensor. Especially important for thermocouples.

Why Use a Transmitter?

Standardize on a single input type for controllers

Add more functionality to the measurement point

- Hot Backup®
- Differential measurement
- Multiple input
- Averaging
- Remote communication
- Allows for fine tuning of measurement system
- Sensor diagnostics – monitors the sensor for indications of impending failure

Controllers, PLCs, and other devices have options to take a temperature measurement signal directly from a thermocouple or RTD so why use a transmitter? There are several good reasons to include a transmitter in your measurement loop. One of the most important is to minimize the sensor lead length to the controller. Leads act as an antenna picking up interference from EMI/RFI, static, and other stray electrical noise. Thermocouples are especially susceptible to this because of their low voltage output.

Some manufacturers offer features that monitor the sensor health and send an alert that maintenance is needed. Others will automatically switch to a backup sensor if the primary sensor fails.

Other common features are multiple sensor inputs to perform differential temperature measurement or averaging of several points.

Lead Wire Error with RTDs

2 wire connection adds lead resistance in series with PRT element

One important reason to use a transmitter is to help eliminate lead wire error in an RTD circuit. Following is a discussion on the effect of lead resistance in RTDs.

Two wire circuits simply add the lead resistance to the sensing element resulting in very large errors. These should not be used for any measurement that requires high accuracy.
A three wire circuit will add no error if each of the three legs have the same resistance. Unfortunately, in the real world, there is a difference and that causes an error. Adding a transmitter at the sensor location eliminates the lead error.

The current potential method or 4 wire circuit is the most accurate and has no lead wire error associated with it. Here there’s a trade-off between running a 4 conductor cable to take the signal directly to a controller, or add a transmitter and use less expensive 2 conductor cable for the 4-20 mA current. A rule of thumb is if the sensor to controller distance is over 250ft then it is a good idea to add a transmitter.

Analog or Smart is the first decision to make when selecting a transmitter. Decide if the extra features of a smart transmitter will be needed for your application or if a simple analog device will do.

Calibration of an analog transmitter is usually very simple requiring a power supply, ammeter, and screwdriver.
If a smart transmitter is desired then you will need to wade through the myriad of options available. Here size does matter in that the larger devices have more options and are more expensive. The two pictured above are identical except that one has HART communications capability and the other does not. Both will mount in most connection heads and have several setup options available. Programming is through a software/interface package or for the HART version a handheld communicator can be used.

Wireless transmitters are growing in popularity and manufacturers are sorting through all the communications possibilities and are settling a few configurations. Some of the factors to consider are which network type will work best for you, security, and reliability. We have all had a cell phone call drop out or a laptop PC wireless internet connection disconnect unexpectedly and those are concerns if using a wireless transmitter to control a process.

Mounting the transmitter is determined by ambient conditions, accessibility to read the indicator, or hazardous atmospheres.
Typical wiring connections for a 4 wire RTD to a head mounted loop powered transmitter
- Power is 24 VDC

Transmitters can be integrated into the sensor housing to create a compact package for restricted space locations.

If several measurement points are located close together a panel or rail mount transmitter may be a good solution. Several can be installed in a very small space.
Ambient conditions can sometimes dictate the location of a transmitter. High or low temperatures may damage the electronics or indicator requiring that the transmitter be mounted close by on a pipe or wall mount.

Hazardous atmospheres will require specially rated enclosures and sensor assemblies.

Indicators are LED or LCD and the selection depends on where it will be used. LEDs are generally difficult to read in bright light but are easily read in low light. Opposite is true for LCD indicators.
LCD Indicator

- Works well in bright light
- May require backlight to read in low light conditions

Installation

Other considerations

- Ambient temperature
  - Most are limited to -40°C to 85°C to protect the electronics – indicators have more limited range
  - Accuracy is affected by the ambient temperature
- Vibration
  - Remote mount may be necessary
- Sanitary wash-down
  - Corrosion resistant coatings and waterproof heads
- Safety Instrumented System (SIS)
  - Requires safety certified transmitter

Battery powered transmitters/indicators are useful for remote locations or where a local indication of temperature is required. Batteries typically last 2 years or more.
At a minimum, the RTD resistance is checked in a temperature bath at the zero and span temperatures. Those resistance values are used to adjust the transmitter output. For those transmitters that have curve fitting capability, a full calibration of the RTD is performed and the resulting coefficients are entered into the transmitter.

The largest sensor error is the interchangeability. Matching the sensor calibration to a transmitter will eliminate about 85% of the error.

ASTM E1137 and IEC 60751 are the two most commonly used standards that define a nominal R vs. T relationship for RTDs. All sensors are manufactured with 0°C as the starting point. Variations in sensors result in the tolerance increasing as the temperature diverges from 0°C.

Note that the ASTM standard has slightly tighter tolerances for the two grades of sensors. All RTDs are built with the tightest tolerance at 0°C and as the temperature diverges from 0°C the tolerance increases. The vertical line on the graph represents 0°C and the tolerance on the y axis is expressed in ± °C from nominal.
These equations can be used to calculate the interchangeability at any temperature. Note that the temperature $t$ is an absolute value in °C. The resultant is the interchangeability in ± °C.

Calculating the interchangeability at 200°C shows the difference between the grades or classes of sensors. Grade A or Class A have the tighter tolerances.

In our example an accuracy improvement from ± .77°C down to ± .11°C was made by matching the sensor to the transmitter. Matching is a very economical method to improve your system accuracy.
Analog transmitter potentiometers are used to make adjustments to the zero and span.

Software is used for smart transmitter setup.

Match RTD to Transmitter
This screen shot shows a typical smart transmitter setup for entering the calibration coefficients and temperature coefficient from a calibrated RTD.

The CVD equation is used in a lot of smart transmitters to interpolate between calibration points. IPTS-68 is still used for industrial applications because it is simpler to apply and still gives acceptable accuracy for numerous processes.

An important first electrical check that should be performed as part of any calibration. If the sensor is out of spec a repeatable calibration cannot be performed.
Using an Ice Bath, check resistance at 0°C

If the sensor passes the IR check then a check in an ice bath should be performed. Crushed ice made with purified water is packed into an insulated container. Purified water is added to fill in the gaps. If the ice floats, you have added too much water. Adding a stirring feature to keep the water flowing around the ice minimizes temperature gradients within the bath. Each probe should be immersed at least 4". Do not use the probe to beat a hole in the ice. You may damage the sensing element. Use a scrap probe or similar rod to form the holes.

If the probe does not meet the resistance tolerance it should be replaced. There is not any reliable and cost effective method to repair it. Save the sensor for recycling! There is $$ worth of platinum in each probe. Save it up for a department lunch.

Some of the equipment required for matching an RTD to a transmitter.
- Software and interface for PC programmable transmitters
- Decade box and ammeter for analog transmitters with adjustment potentiometers.
Manufacturers seem to have many different ways to report transmitter performance. Here are three that range from simple to complex. Be careful when comparing devices to insure you get the performance you need.

As with anything eventually a transmitter will fail and some trouble shooting is necessary to see if it is an installation problem or if the device has failed.

High quality connecters, spade lugs, or tinned leads are good methods to connect a transmitter to a sensor. The connection head shown in the lower right corner had a lot of electrically conductive dust in it that caused some electrical leakage between the terminals resulting in a bad temperature reading.
A stray wire strand can easily short the terminals together on a transmitter or terminal block.

Most common failure mode is due to voltage spikes such as from welders and lightning:
- Causes output to lock. No response from the transmitter when the input resistance is varied.

Questions?

Contact us at 800-328-3871
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