Precision Digital Presents

Intro to Thermocouples, RTDs, and Temperature Transmitters

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Agenda, Objectives & Takeaways

Define thermocouples, RTDs, and temperature transmitters

Understand how thermocouples, RTDs and temperature transmitters work

Evaluate the pros and cons of each type

Getting to know you

- Where are you located?
- What is your industry?
- What is your level of expertise?

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Terms

Thermocouple

Measures temperature by correlating the voltage differential between the junction of two different metal alloys and a reference voltage, to temperature

RTD

Measures temperature by correlating the resistance of a resistive element (usually fine coiled wire) with the temperature

Temp Transmitter

Converts the low-level signal (Ohms or mV) generated by one of these temperature sensor types and converts it into a higher power level (4-20 mA or digital) signal that can be transmitted over long distances

Thermocouples

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What is a thermocouple?

Most popular type of temperature sensor.

Can measure wide range of temperatures

Are interchangeable and have standard connectors

Two thin metal wires welded together to form a junction

Almost any type of metal can be used. There are preferred metals used for their predictable output voltages and ability to withstand large temperature gradients

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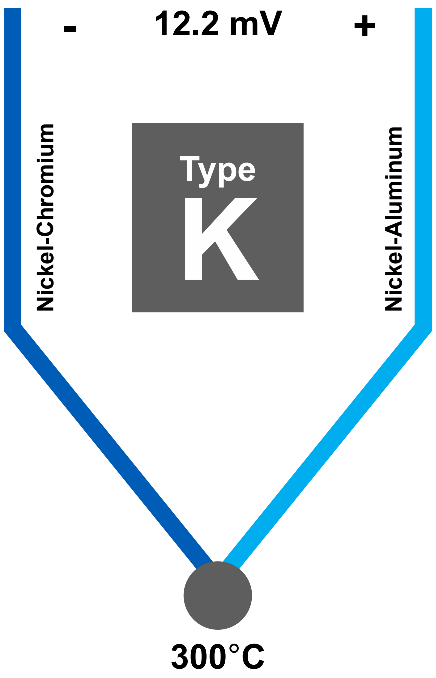
How it works



- The junction between two metals generates a voltage that is a function of temperature
  - This is known as the thermoelectric or Seebeck Effect
- The picture shows two different metal alloy leads welded together to form a thermocouple junction.
- That differential is measured and compared with the known voltage/temperature relationship to determine the temperature of the environment being measured.

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Reading the Signal

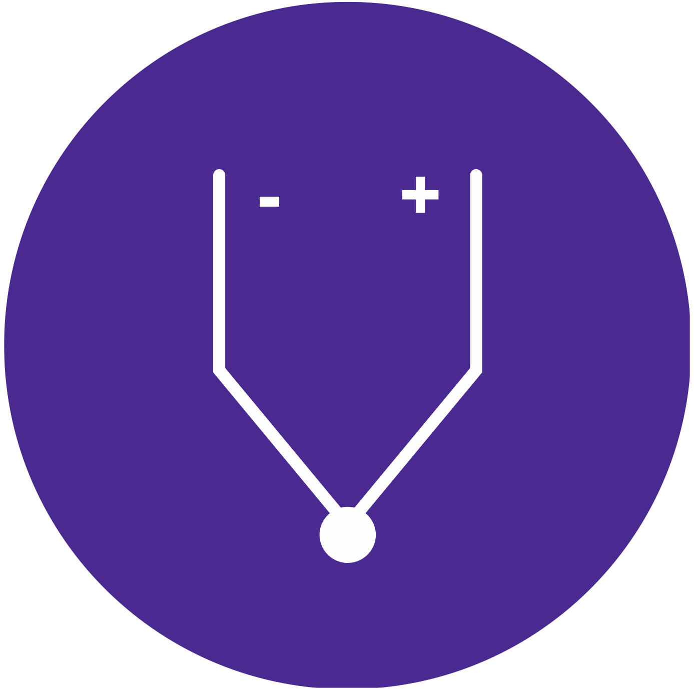
- It is not possible to simply measure the voltage differential directly and the metal leads of a voltmeter would create an additional thermocouple junction.

- Measurement devices use Cold Junction Compensation (CJC) in order to compensate for this.

- Thermocouples do allow for a second junction as long as that second junction is kept at 0 °C (hence cold junction). Traditionally this was done by keeping the junction submerged in ice water.
- Modern applications measure the junction temperature voltage as well, and use it to calculate the 'true temperature.'
- A thermocouple's output is also nonlinear complex polynomial equation.

Types of Thermocouples

- Thermocouples are made from different metal alloy pairs which all have different characteristics such as temperature range and accuracy.
- Thermocouples come as either:
  - Bare wire ‘bead’ which is low cost
  - Built into probes such as needle, insulated, catheter, capsule, direct immersion, surface mount, and micro-thermocouple



Types of Thermocouples – Save for Later!

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Type K

- General purpose TC
- Low-cost and highly available in wide array of probes
- Available in -200°C to 1200°C
- Sensitivity is ~ 41 µV/°C

Type E

- Has a higher output (68 µV/°C) which makes it well suited for low-temperature (cryogenic) use

Type N

- Suitable for high temp measurement at lower cost than platinum TCs (type B, R, S)
  - High stability and resistance to high temperature oxidation
- Can withstand temperature above 1200 °C

Type J

- Less popular than type K. Used with older equipment that cannot accept modern thermocouples
- Limited range of -40 °C to 750 °C
- Sensitivity of ~ 52 µV/°C

Type B, Type R, Type S

- Platinum TCs suitable for high temp measurements only (>1600 °C).
- High cost and low sensitivity make them not suitable for general purpose use.
- Type B TCs, due to the shape of their temp / V curve, give the same output at 0 °C and 42 °C making them useless below 50 °C.

Type	Composition	Range °C
Type B	Pt-30% Rh vs. Pt-6% Rh	0 to 1820
Type E	Ni-Cr alloy vs. a Cu-Ni alloy	-270 to 1000
Type J	Fe vs. a Cu-Ni alloy	-210 to 1200
Type K	Ni-Cr alloy vs. Ni-Al Alloy	-270 to 1372
Type N	Ni-Cr-Si alloy vs. Ni-Si-Mg alloy	-270 to 1300
Type R	Pt-13% Rh vs. Pt	-50 to 1768
Type S	Pt-10% Rh vs. Pt	-50 to 1768
Type T	Cu vs. Cu-Ni alloy	-270 to 400

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Considerations for using thermocouples

Connection Problems

Measurement errors can be caused by unintentional thermocouple junctions. If longer length thermocouples leads are needed, use correct type of thermocouple extension wire

Lead Resistance

TC wires are very thin and have high resistance and therefore can experience signal noise or errors due to the input impedance of the measuring device. TC leads should therefore be kept short. If long leads are needed, use proper thermocouple extension wire, which is thicker.

Noise

The millivolt output of a thermocouple is very prone to signal noise. Interference can be minimized by twisting both wires together to ensure they both pick up the same noise.

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Considerations for using thermocouples

De-Calibration

Thermocouple wire makeup can alter over time at the extremes of operating temperature. Make sure probe insulation is sufficient for operating environment. Element oxidation and corrosion can also effect calibration and function.

Thermal Shunting

The mass of the thermocouple, mounting location, and self heating/cooling may affect the ability to read an accurate temperature. Consider high-mass probed when change rate is critical. Be aware of heat dissipation issues when full-emersion is not possible.

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Thermocouples Pros and Cons

Pros

- Popular in most temperature measurement applications
- Low Cost
- Robust and resistant to shock and vibration
- Wide temperature range
- Simple to manufacture
- Require no excitation power
- No self-heating
- Can be made very small

Cons

- Produce relatively low, non-linear output signal
- Requires a sensitive and stable measuring device
- Low signal level, so very noise susceptible

RTDs

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What is an RTD?

Resistance Temperature Detectors (RTDs) are sensors used to measure temperature

Generally greater stability, accuracy, and repeatability when compared to thermocouples

Slowly becoming the preferred temperature measurement device in many industrial applications because of high accuracy and therefore suitability for precision applications.

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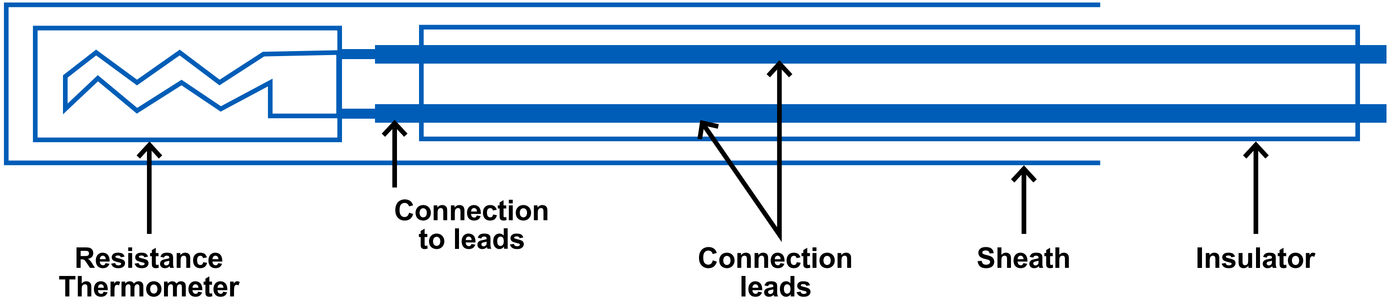
How it works



- Most RTD elements are made from a length of fine coiled wire of a pure material, typically platinum, nickel or copper, wrapped around a ceramic or glass core.
- The material has a predictable change in resistance as the temperature changes.
- RTDs work by correlating the resistance of the element with temperature. The hotter a metal becomes, the greater its resistance.
- Platinum is typically used
  - linear resistance vs. temp, chemically inert, and stable over temp

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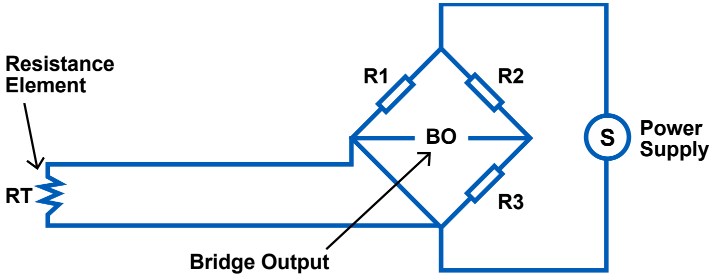
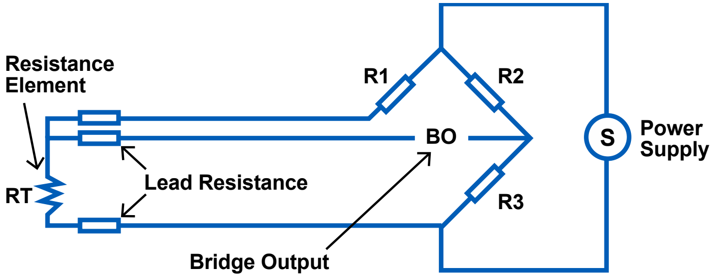
Reading the signal

- Unlike thermocouples, RTDs require a small amount of current
    - Small self-heating inaccuracies possible
- The resistance measured correlates to temperature
- Lead wire resistance can contribute to measurement error, especially as wire length increases
    - Three and four-wire options help eliminate this error

Different Types of RTDs





Two-wire

- Only used when high accuracy is not required
  - Resistance of connecting wires is added to that of the sensor, leading to measurement errors

Three-wire

- The two leads to the sensor are on adjoining arms
  - There is a lead resistance in each arm of the bridge so that the resistance is cancelled out as long as the two lead resistances are the same

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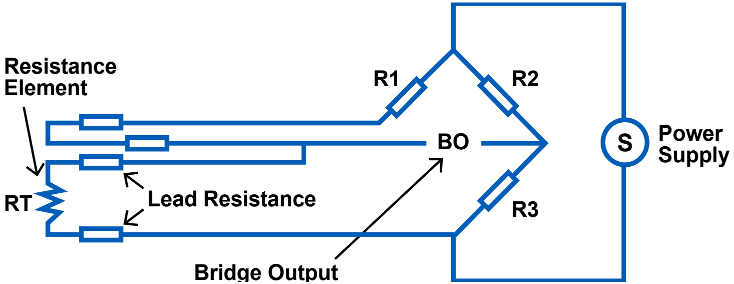
Different Types of RTDs (continued)



Four-wire

- Four-wire is most accurate RTD temperature measurement setup
  - The device measures and removed the lead resistance in both sets of leads

- RTDs are also made from different materials
  - RTDs can be made cheaply in Copper and Nickel, but these have restricted ranges because of non-linearity and wire oxidation problems in the case of Copper.
  - Platinum is the preferred material for precision measurement because in its pure form the Temperature Coefficient of Resistance is nearly linear; enough so that temperature measurements with precision of ±0.1 °C can be readily achieved with moderately priced devices.

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RTD Curves

- Different materials and standards require a different resistance to temperature coefficient (RTD Curve)
- The RTD specification will indicate the curve necessary
- The 100 Ohm, 385 Temperature Coefficient Platinum RTD is nearly a universal standard in the process control world.

Element Code	Material	Base Resistance	TCR Ohms Ohms/°C	Description
PJ	Platinum	25.5 Ω at °C	0.00392	Commonly used in laboratory standards (1-25)
PIA	Platinum	100 Ω at 0.01°C	0.00393	ITS-90 reference curve
PA	Platinum	100 Ω at 0°C	0.00392	IPTS-68 Standard (11-100)
PB	Platinum	100 Ω at 0°C	0.00391	(11-100)
PC	Platinum	100 Ω at 0°C	0.00389	Canadian specification
PD	Platinum	100 Ω at 0°C	0.00385	Meets IEC 751 (1995) (5-100)
PE	Platinum	100 Ω at 0°C	0.00385	Nominal IEC curve but looser tolerance (5-100)
PY	Platinum	98.129 Ω at 0°C	0.003923	Meets SAMA RC21-4-1966
PK	Platinum	200 Ω at 0°C	0.00392	(1-200)
PN	Platinum	200 Ω at 0°C	0.00385	(5-200)
PL	Platinum	470 Ω at 0°C	0.00392	(1-470)
PH	Platinum	500 Ω at 0°C	0.00392	(1-500)
PP	Platinum	500 Ω at 0°C	0.00391	(11-500)
PG	Platinum	500 Ω at 0°C	0.00385	(5-500)
PF	Platinum	1000 Ω at 0°C	0.00385	(5-1000)
PW	Platinum	1000 Ω at 0°C	0.00375	
PS	Platinum	10.000 Ω at 0°C	0.00385	
CA	Copper	9.035 Ω at 0°C	0.00427	(16-9)
CB	Copper	1000 Ω at 0°C	0.00427	
NA	Nickel	120 Ω at 0°C	0.00672	Standard Minco nickel ("Nickel A") (7-120)
NB	Nickel	100 Ω at 0°C	0.00618	Meets DIN 43760 for nickel elements
FA	Nickel-Iron	604 Ω at 0°C	0.00518	(15-604)
FB	Nickel-Iron	908.4 at 0°C	0.00527	1000 Ω at 70°F (19-1000)
FC	Nickel-Iron	1816.81 Ω at 0°C	0.00527	2000 Ω at 70°F (19-2000)

RTDs Pros and Cons

Pros

- Stable output for long periods of time
- Ease of recalibration
- Accurate readings over relatively narrow temperature spans

Cons

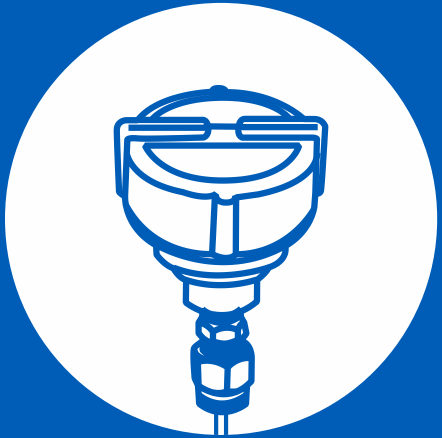
- Smaller overall temperature range
- Higher initial cost
- Less rugged in high vibration environments
- They require more complex measurement circuits
- Self-heating and lead errors when high accuracy is needed

Getting to know you

- What is your primary application?

Questions?

- Please enter your questions in the ‘Questions’ window



Temperature Transmitters

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What is a Temperature Transmitter

- There are two ways to get the reading from the temperature device to its final destination:
  - Attach the end unit directly to the low-level signal (Ohm or mV) which may or may not require the use of sensor extension wires (thicker, fragile, and expensive) depending upon the distance from the sensor to the meter
  - Install a temperature transmitter to take the low-level signal and convert it into something that can be transmitted long distances.
- A temperature transmitter reads the thermocouple or RTD input and outputs a high-level analog or digital signal (such as a 4-20 mA current loop or Modbus® serial communications

Temperature Transmitters Pros and Cons

Pros

Advantages of using a temperature transmitter as opposed to measuring temperature directly from sensor:

- Can include local indication and control
- Much greater noise resistance, especially over long distances
- Isolate, amplify, filter noise, linearize, and convert the input signal from the sensor
- Output signals work with many standard devices
- Does not require expensive extension wire

Cons

Disadvantages of using a temperature transmitter:

- Adds additional cost to the temperature measurement system

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Summary

1. Define thermocouples, RTDs, and temperature transmitters
2. Understand how thermocouples, RTDs and temperature transmitters work
3. Evaluate the pros and cons of each type

Getting to know you

- How often do you specify digital displays?

Q & A

- Please enter your questions in the ‘Questions’ window
- Apologies if we do not get to your question today. We’ll contact you offline with a response as soon as possible.

Next Webinar – July 28th

Loop-Powered Devices, The Fundamentals

An introductory class for those who have to deal with two-wire loop powered devices, but are not electrical engineers. This is a new live broadcast of this popular webinar.

- Understand the key criteria for using or specifying a loop-powered device
- Know if a loop-powered device is qualified for your application
- Decide if loop-power is your best choice

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