Quantum Automation TECH CORNER with Alex Stipe

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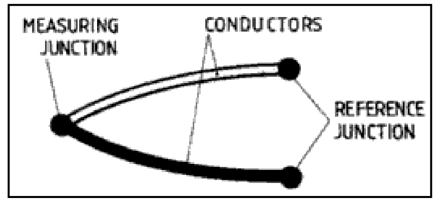
Temperature Measurement Basics: RTD or Thermocouple?

Whether you're an OEM, integrator, end user, or anyone in between, you probably use some form of temperature monitoring in one or more of your applications. This month, I am continuing with the theme of temperature control with an introduction to Thermocouples and RTDs. This article will help you understand how they function and when each one should be used. There's a lot more than meets the eye to temperature measurement.

Thermocouples

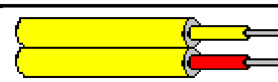
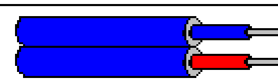
➢ <u>What are they?</u>:

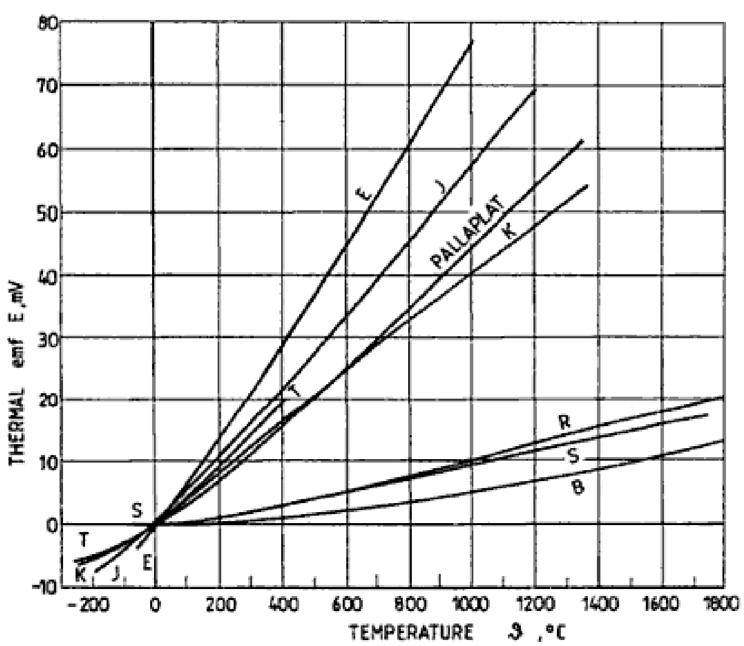


A thermocouple is a device that allows one to measure temperature electronically, in place of a traditional thermometer. Physically, it's composed of two dissimilar conductors joined at one end, called the measuring junction. The opposite ends (the reference junction) hook up to a measuring device that measures the voltage difference between them. The voltage reading can then be converted to a temperature using a scale corresponding to the composition of the conducting wires.

Thermocouples work by utilizing the Seebeck effect, "the development of a voltage in a conductor as a result of a temperature differential" (Fundamentals of renewable energy processes By Aldo Vieira Da Rosa). This can be explained by thinking of electricity as a gas or liquid. Electrons, like gas or liquid molecules (think water), concentrate themselves in colder temperatures and disperse in warmer conditions. Therefore, if one portion of a circuit is hotter than the other, electrons or molecules will want to move towards the colder portion. In an electric circuit, this movement creates current. Since a thermocouple circuit is not complete, current cannot flow but instead induces a voltage between the two mettalic conductors. This voltage can then be measured and scaled to a temperature value for use or display.

- **Thermocouple Overview**:
  - Can achieve accuracy to within ±1-2°C
  - Work well in vibrating applications due to structural integrity
  - Low electrical stability
  - Can be manufactured with less expensive metals
  - No errors caused by lead wire resistance
  - Fast response time, sub second
  - Multiple varieties, the three most common are listed below:

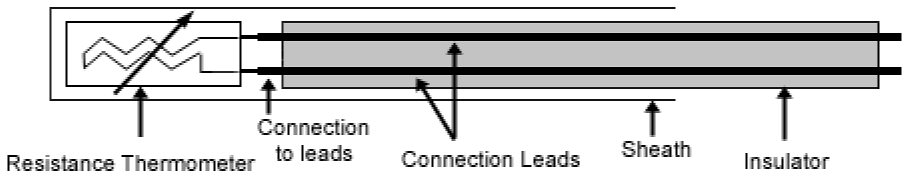
Type	Composition	Temp. Range	Sensitivity	Color Code
K	Nickel-Chromium (+) / Nickel-Aluminum (-)	−200 to +1350 °C	41 µV/°C	 + -
J	Iron (+) / Copper-Nickel (-)	−40 to +750 °C	55 µV/°C	 + -
T	Copper (+) / Copper-Nickel (-)	−200 to 350 °C	43 µV/°C	 + -



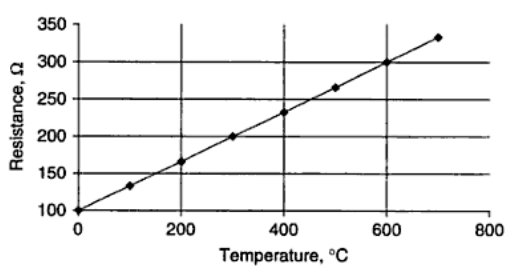
Thermal emf, *E*, of commonly used thermocouples as a function of temperature

Resistance Temperature Device (RTD)

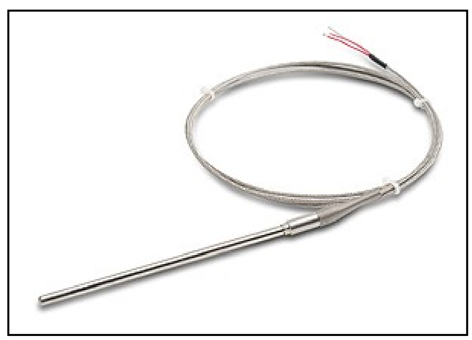
- What are they?:



A Resistance Temperature Device (RTD) is the second most common device used for measuring temperature electronically. Readings are obtained by measuring the electrical resistance of a thin metal wire as its temperature changes. The most commonly used material is Platinum due to its high electrical resistivity, chemical inertness, and good temperature vs resistance linearity (see figure below). Ideally, the sensing device should have a perfectly linear relationship, making resistance to temperature conversions simple and easily scalable.

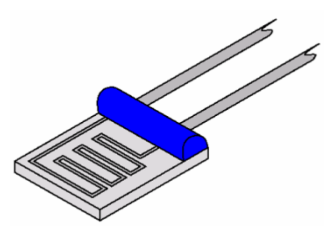


Typical RTD temperature-resistance characteristics

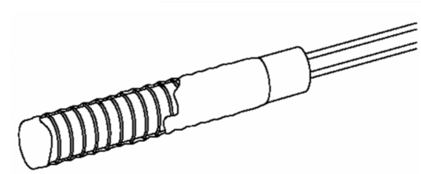


An RTD operates on the principle that near room temperature, the electrical resistance of a typical metal is directly proportional to its temperature (i.e. temp. goes up, resistance goes up). On the molecular level, this can be explained by examining the process of heat transfer. As discussed in last month's TechCorner article, when a metal heats up, it's really absorbing energy from somewhere else. This additional energy causes the individual molecules to increase their rate of vibration. Now, when an electrical current is established across the conductor, electrons have a much harder time traveling towards the negative pole through the oscillating molecules. This, in turn, translates to a higher resistance sensed by the measuring device which is then converted to a higher value in the chosen temperature scale.

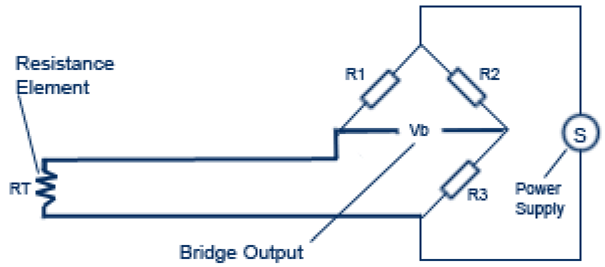
- RTD Overview:
  - Can achieve accuracy within ± 0.3°C
  - Relatively immune to electrical noise
  - Stability and ruggedness dependent on construction
  - Usually contains the precious metal platinum, increasing cost
  - Lead wire resistance can lead to measurement errors if not corrected or compensated-for with a 3 or 4 wire RTD
  - Slower response time, .5 sec -5 sec
  - Available in a variety of form factors:
    - Thin Film:
      Layer of platinum on a thin substrate, low cost, fast response, susceptible to “strain gauge” effects and stability issues



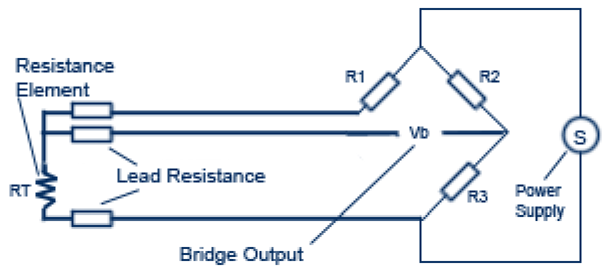
    - Wire-wound:
      Thin wire is wrapped around a cylindrical substrate in a helical pattern, greater accuracy than thin film; coil diameter determines stability (mechanically and electrically)



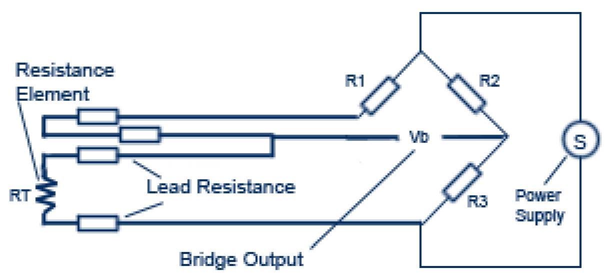
  - Multiple wiring Configurations Available:
    - 2-Wire: Most basic configuration, low accuracy, up to 100m of cable



- 3-Wire: higher accuracy via reference lead, up to 600m of cable



- 4-Wire: highest accuracy and reliability, zero lead wire resistance error, up to 15Ω cable resistance allowable



Which one should you use?

Now that you know a little bit more about how thermocouples and RTDs function, you should be able to make an educated decision as to which one to use for your application. Here are the main selection points to consider:

1. Temperature Requirements:
   - ✓ RTDs have an effective range of about -200°C to 500°C. Over 500°C the platinum element can become contaminated by the sheath material.

- ✓ Thermocouples are effective between -180°C and 2320°C. They are your only choice for reliable contact temperature measurement above 500°C.

2. Accuracy and Stability:
   - ✓ RTDs provide a much higher level of accuracy and stability. They can be accurate down to the tenth of a degree and their construction creates a stable response within their effective temperature range.
   - ✓ Thermocouples usually see accuracy no better than one or two degrees. They are also usually less stable due in part to their susceptibility to electrical noise.
3. Response:
   - ✓ RTDs generally have response times between one and five seconds but can be much longer depending on the particular model used.
   - ✓ Thermocouples can provide response times under a second.
4. Application Medium:
   - ✓ RTDs run into issues when used in mediums with low heat transfer coefficients. During operation, a small amount of current must pass through the platinum element to measure its resistance. This current creates a small amount of heat which must be removed in order to avoid affecting the resistance your end device reads.
     i. Air is about 100 times less effective at transferring heat
5. Size:
   - ✓ Due to construction limitations, RTDs range from ~3mm – 6mm.
   - ✓ Thermocouples can be less than 2mm in diameter.
6. Cost:
   - ✓ RTD's are generally 3-4 times the cost of Thermocouples

Conclusion

If you require high accuracy and your application is less than 500°C then a 4-wire Pt100 RTD will be your best choice. Starting at $29.00 you can't go wrong with the RTD0100 series from AutomationDirect. If accuracy is less of an issue but price and temperature range are, then the J and K type thermocouples from ADC will be the perfect finish to your system.

References:

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Wikipedia:

Seebeck Effect