Resistance Temperature Detectors

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Image source: http://www.omega.com/ppt/pptsc_lg.asp?ref=1PT100G_RTD_ELEMENTS&Nav=

Resistance temperature detectors (RTDs) are often made of platinum

- Why platinum?
  - Stable element
  - Resists corrosion
  - Easily workable
  - High melting point
  - Easily purified

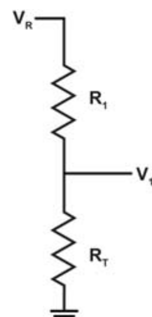
Source: http://www.diamond-studio.co.uk/jewelleryshop/

Source: http://www.campbellsci.com/hmp50

Platinum RTD Transfer Equation

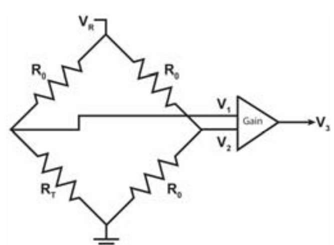
- R_0 = Resistance at T_0 (usually, T_0 = 0°C)
- a = first-order temperature coefficient
- b = second-order temperature coefficient
- R_T = resistance of the sensor at temperature T
- For a typical platinum RTD:
  - a = 3.85×10^{-3} °C^{-1}
  - b = -5.85×10^{-7} °C^{-2}

A simple platinum RTD application: Voltage divider



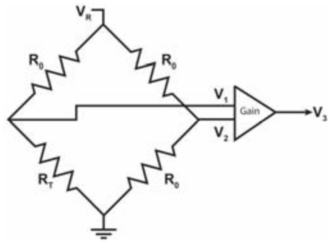
A better platinum RTD application: Bridge circuit

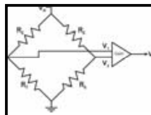
Let: $R_0 = R_T$ at 0°C
V_R = 5 V
Then at 0°C, V_3 = 0 V



A better platinum RTD application: Bridge circuit

Now assume that 50°C is the maximum temperature that we care to measure in the field…





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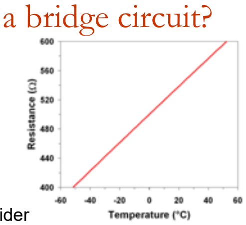
A better platinum RTD application: Bridge circuit

Say we want the output of the sensor at the maximum temperature (50°C) to be 5 V. Since we know that the input is 5 V, the required gain is therefore ___________.

A better platinum RTD application: Bridge circuit

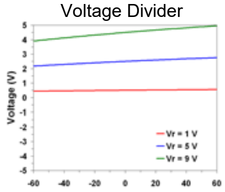
For a 0±5 V system, we now use the entire span!

Why use a bridge circuit?

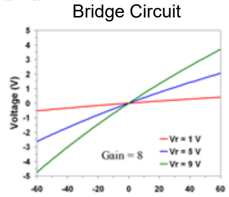


Resistance vs. Temperature for a Platinum RTD

Voltage Divider



Bridge Circuit



Static sensitivity of a platinum RTD in a bridge circuit

Uh-oh…Don't resistors dissipate heat?

- If we pass a current through a conductor with non-zero resistance, the conductor will consume power and dissipate heat
- The resulting "self-heating" of the sensor will cause an error
- The self-heating specification (in terms of power per degree C) describes the relationship between this temperature increase and the power dissipation for a given transducer

Power dissipated by an RTD

Power dissipated by an RTD

- Say we have a sensor with a self-heating specification of 4 mW °C^{-1} and we are willing to tolerate a maximum self-heating error of 0.1°C
  - Must limit current flow to avoid exceeding tolerable error
  - This sets an upper limit on V_R

How to select the gain and input voltage

- Since we are limited by the self-heating specification and self-heating error to a power dissipation of 0.4 mW, we must now determine the maximum allowable input voltage
- This ensures that the current through the bridge circuit is low enough to avoid exceeding the maximum allowable power dissipation
- For $R_T = R_0 = 500\ \Omega$,

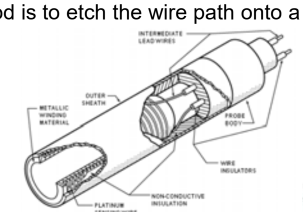
How to select the gain and input voltage

- Now calculate the necessary gain so that V_3 is as close as possible to 5 V for our bridge circuit example:

A gain of ___________ is necessary, given the required maximum input voltage, so that the output is 5 V at 50°C.

How are RTDs typically made?

- Wrap a fine wire (e.g., platinum) around a substrate (a substrate is some supporting material on which a circuit is formed or fabricated)
- Cut the wire to the appropriate length to create a precisely known resistance at T = 0°C
- Since the wire is very fragile, the form must be chosen such that it has a small β (e.g., glass)
- Another method is to etch the wire path onto a small circuit board



Source: http://www.rdfcorp.com/anotes/pa-r/pa-r_01.shtml

RTD Advantages

- Low resistance: 100 Ω (most common) to 1000 Ω
- High sensitivity compared with thermocouples
- Very accurate (±0.0006°C to 0.1°C)
- Nearly linear over a wide temperature range (more so than thermocouples)
- Wide span of operating temperatures (-200°C to 850°C)
- Operates in high temperatures
- High repeatability and stability
  - Low drift (industrial models drift < 0.1°C $year^{-1}$)
  - Precision RTDs may drift only 0.0025°C $year^{-1}$

RTD Disadvantages

- Fairly expensive (they're made of platinum!)
- Low static sensitivity
- Requires excitation and supporting circuitry
- Fragile wire (sensitive to shock and vibration)
- Low absolute resistance (i.e., resistance of long lead wires can affect sensor accuracy)
- Self-heating error
- Slow response time