TEMPERATURE SENSORS

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AGENDA

- Why measure temperature?
- Characteristics of interests
- Types of temperature sensors
  1. Thermistor
  2. RTD Sensor
  3. Thermocouple
  4. Integrated Silicon Linear Sensor
- Sensor Calibration
- Signal Conditioning Circuits

WHY MEASURE TEMPERATURE?

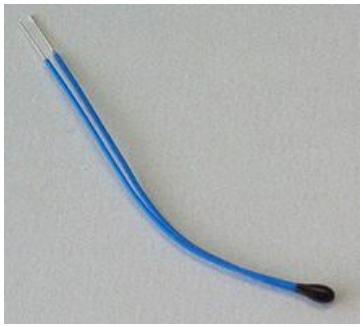
Desired Characteristics

- High sensitivity
- Large temperature range
- Accuracy
- Repeatability
- Relationship between measured quantity and temperature
  - Nonlinear
  - Linear
- Easy calibration
- Fast response

Any non-ideal factors you should know of?

Types of Temperature sensors

1. Thermistor
2. Resistive Temperature Device (RTD)
3. Thermocouple
4. Integrated Silicon Linear Sensor



Choosing a Temperature Sensor

Q1: What is the desired temperature range?

Q2: What is the tolerable limit to the error in measurement?

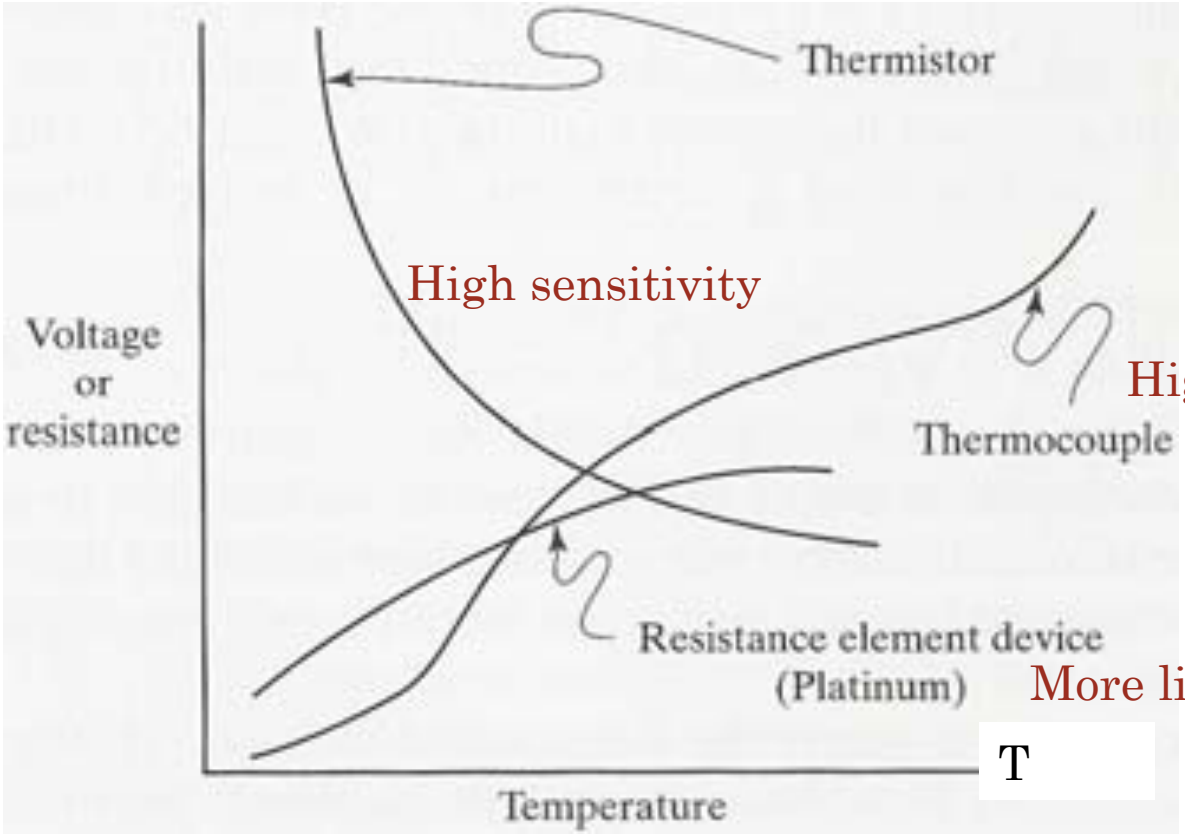
Q3: What are the conditions under which the measurement is to be performed?

Q4: Are there any performance and cost constraint?

Main Characteristics Comparison

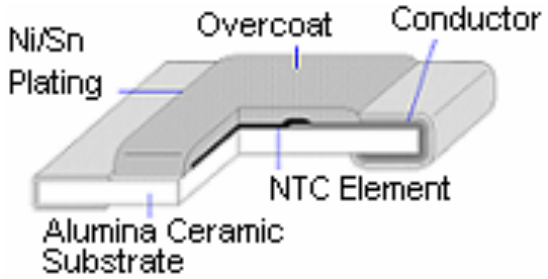
- Read more details in application notes AN 679

http://ww1.microchip.com/downloads/en/AppNotes/00679a.pdf



1. THERMISTOR

- High sensitivity*
- Inexpensive
- Reasonably accurate
- Lead resistance ignored
- Glass bead, disk or chip thermistor
- Typically Negative Temperature Coefficient (NTC), PTC also possible
- R-T mode (zero-power mode): nonlinear relationship between R and T



1. THERMISTOR R-T CHARACTERISTICS:

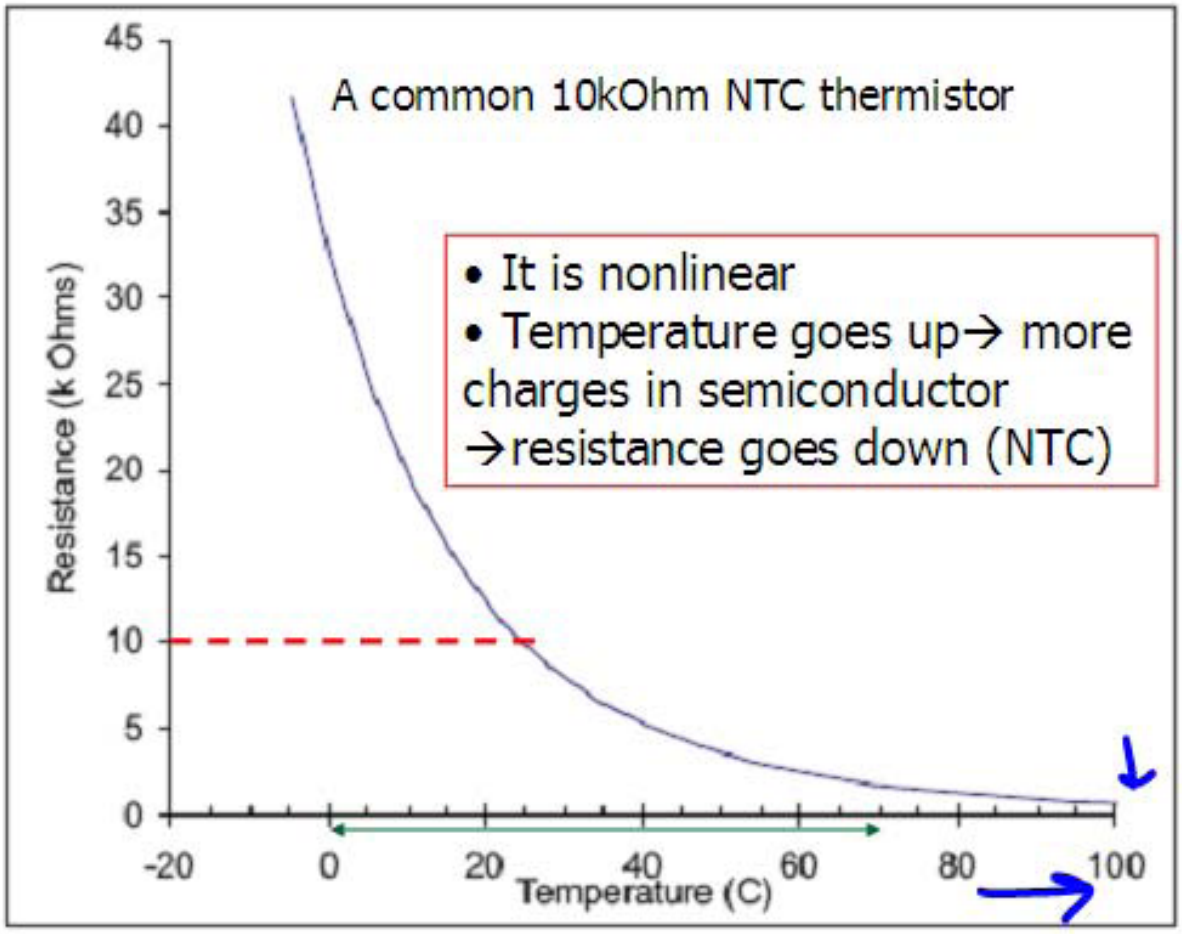


Figure 1. NTC R-T response curve.

Reference: http://www.eng.hmc.edu/NewE80/PDFs/VIshayThermDataSheet.pdf

1. THERMISTOR MODEL

$$R = Ae^{(\beta/T)}$$

$$\beta = \frac{T_1 * T_2}{T_2 - T_1} \ln \frac{R_1}{R_2}$$

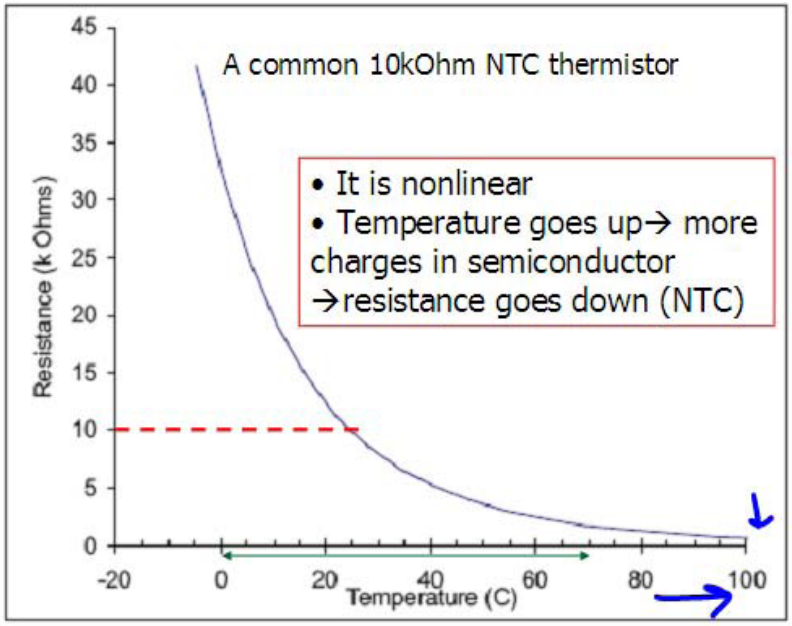


Figure 1. NTC R-T response curve.

β 0°C/50°C

1. THERMISTOR STEINHART-HART (S-H) EQUATION

- Emperically derived polynomial formula
- Some variations in S-H Equations

Form #1 :

$$\frac{1}{T} = C_1 + C_2 \ln(R) + C_3 (\ln R)^3$$

Form #2 :

$$\ln R = B_0 + \frac{B_1}{T} + \frac{B_3}{T^3}$$

http://www.eng.hmc.edu/NewE80/PDFs/VIshayThermDataSheet.pdf

1. THERMISTOR STEINHART-HART (S-H) EQUATION

$$\frac{1}{T} = C_1 + C_2 \ln(R) + C_3 (\ln R)^3$$

How to find C_1, C_2 and C_3?

→ Calibration

Calibration Of A Sensor (Thermistor)

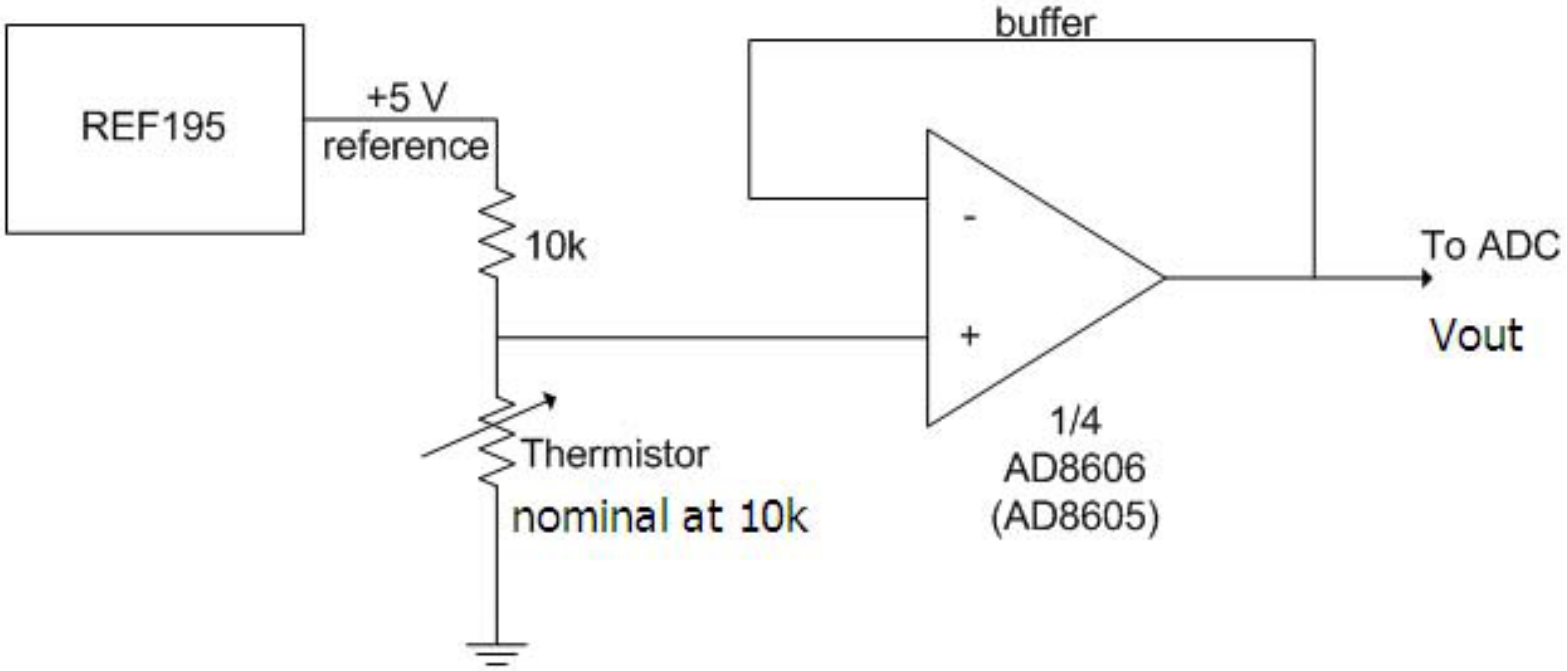
- Passive, requires either current or voltage source
- Voltage divider circuit (relate voltage and resistance)
- 3 Unknowns

- More samples for better curve fitting
- Linear regression / Least square fit
- Matlab (Use REGRESS(Y,X))/Excel/KaleidaGraph

http://en.wikipedia.org/wiki/Linear_regression

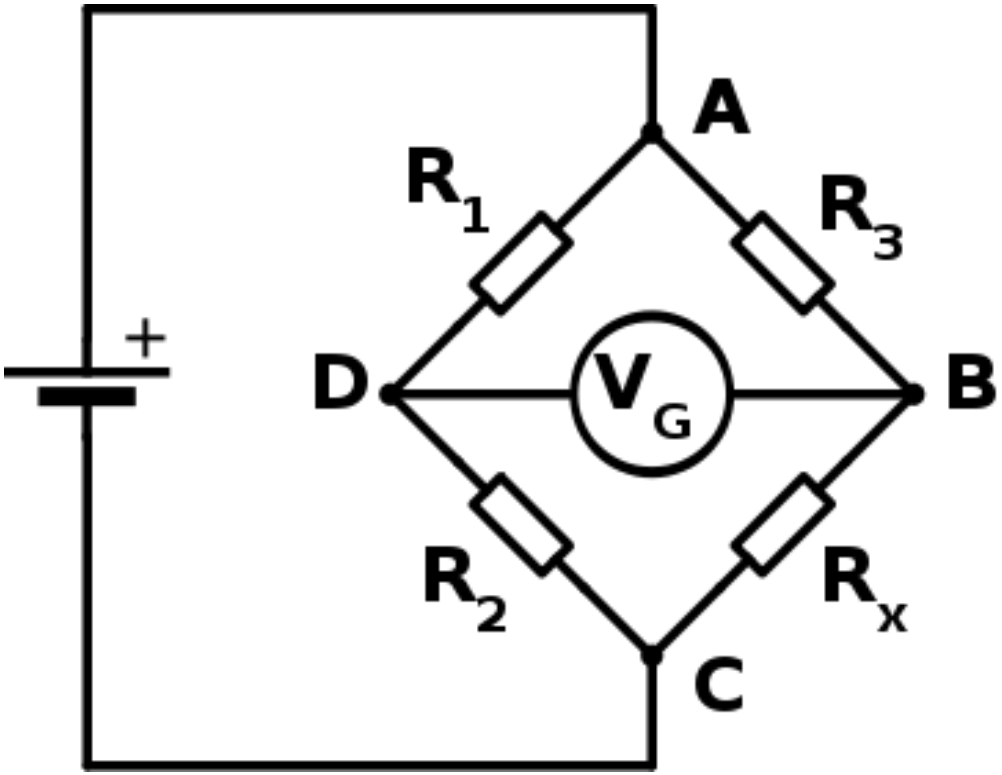
http://mathworld.wolfram.com/LeastSquaresFitting.html

1. THERMISTOR: SETUP IN LAB



http://ww1.microchip.com/downloads/en/AppNotes/00685b.pdf
For more thermistor signal conditioning circuits

1. THERMISTOR: SETUP A BRIDGE CIRCUIT



http://en.wikipedia.org/wiki/Wheatstone_bridge

2. Resistance Temperature Device (RTD)

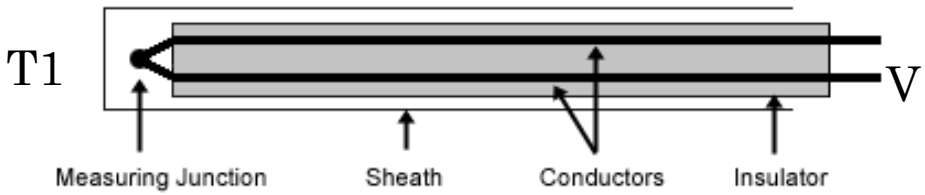
- Very Accurate and stable
- Reasonably wide temperature range
- More expensive (platinum)
- Positive Temperature Constant, and rather constant
- Requires current excitation
- Smaller Resistance range
  - Self-heating is a concern
  - Lead resistance is a concern

→ More complicated signal conditioning circuit

Read AN 687 for more details (e.g. current excitation circuit):
http://ww1.microchip.com/downloads/en/AppNotes/00687c.pdf
http://www.control.com/thread/1236021381 on 3-wire RTD

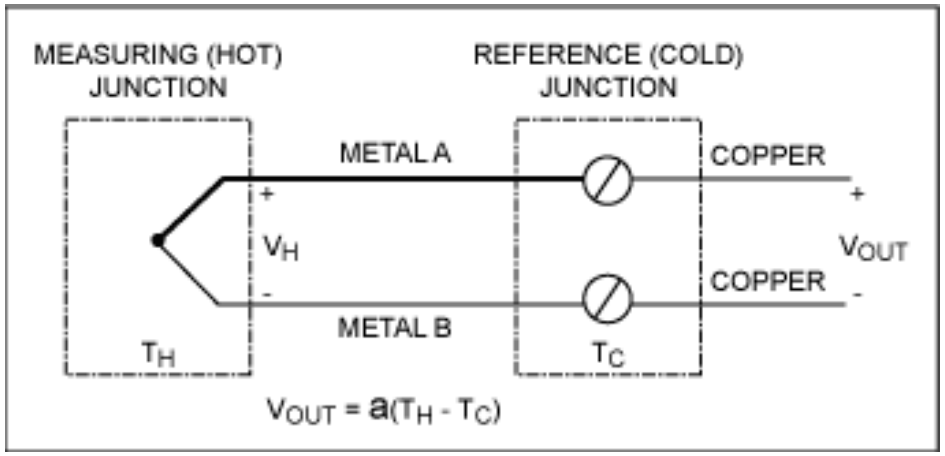
3. THERMOCOUPLE

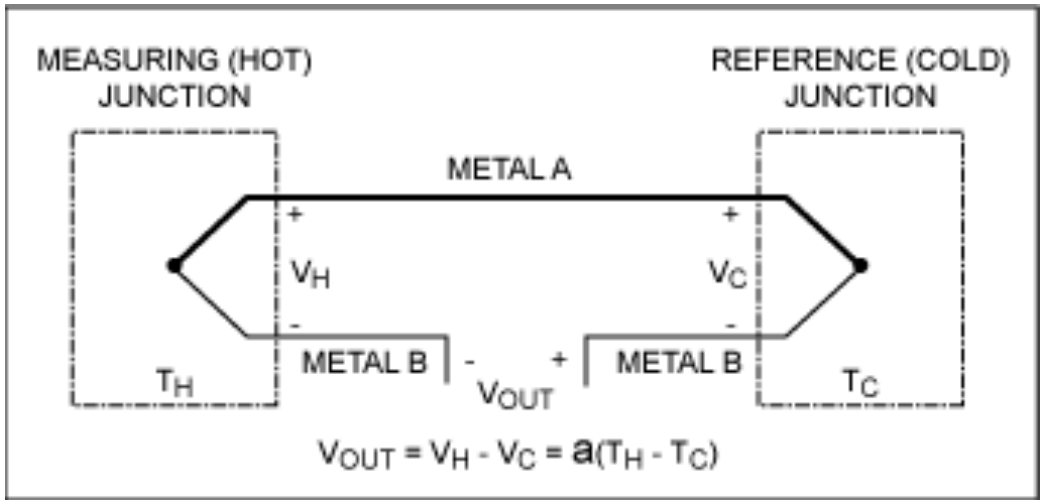
- High temperature range
- Inexpensive
- Stand tough environment
- Made from Platinum or Platinum-Rhodium
- Requires reference junction
- Fast response
- Output signal is usually small



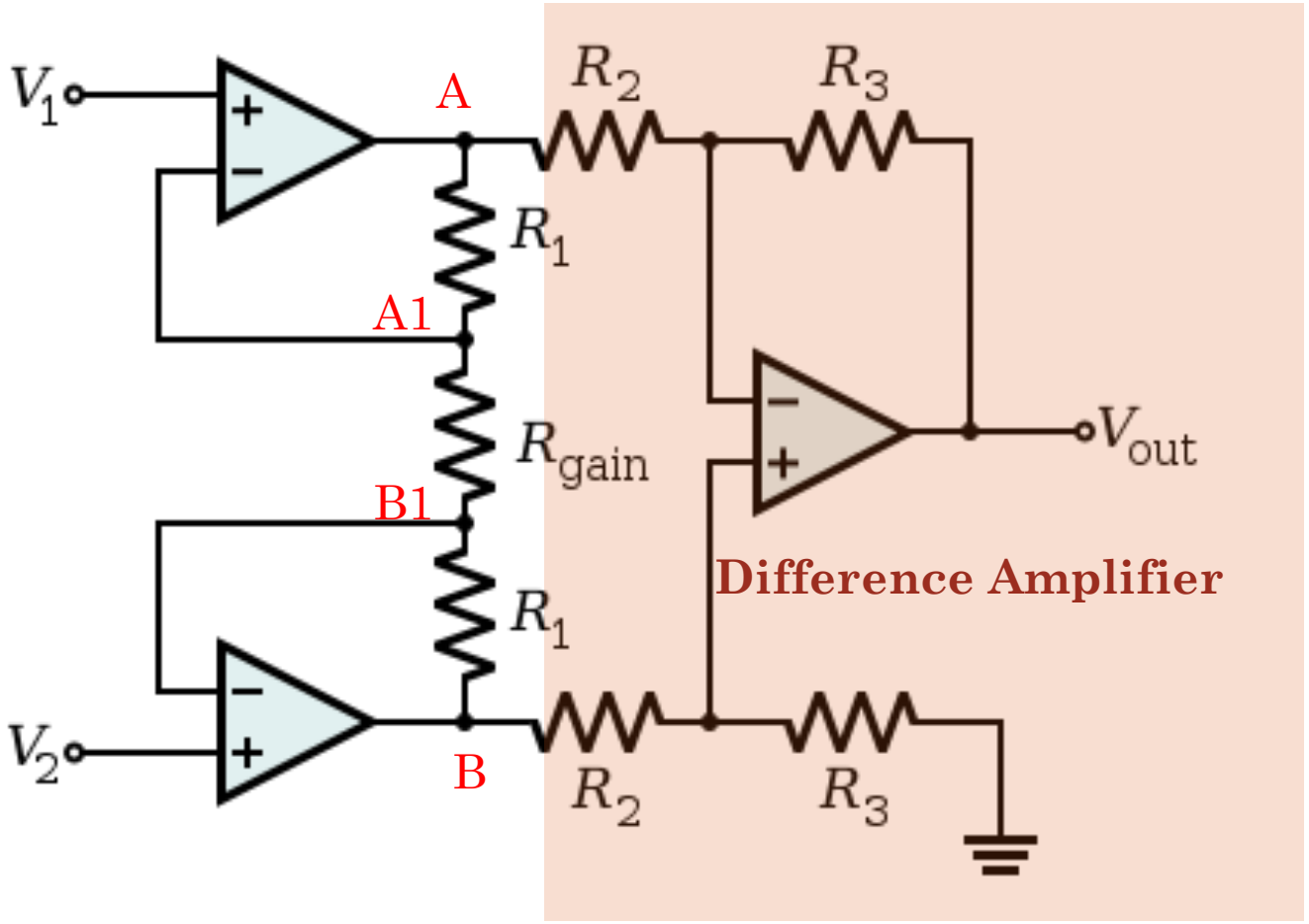
The principle: If two conductors of different materials are joined at one point, an EMF is created between the open ends which is dependent upon the temperature of the junction. As T1 increases, so does V. The EMF also depends on the temperature of the open ends T2 (reference).

3. THERMOCOUPLE (REFERENCE)





3. Thermocouple: Instrumentation Amplifier Circuit



3. Thermocouple Setup in the Lab

http://datasheet.octopart.com/AD628ARZ-Analog-Devices-datasheet-16080.pdf

For more details on difference amplifier.

4. Integrated Silicon Linear Sensor

- Integrated form
- -40°C to +150°C
- Limited accuracy +/- 2 degree
- Linear response (no calibration is required)
- Direct interface with ADC

More details:
http://ww1.microchip.com/downloads/en/DeviceDoc/21942e.pdf

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Enjoy the fun in the lab!