Aero Sensors part B
Measuring temperature

Why measure temperature?

- Temperature is useful to know:
  - It might be a variable in another process we want to monitor.
  - Often components and systems can only operate over a certain range of temperatures – we may need to monitor and control it.
  - Also temperature is associated with energy dissipation – we can use it to look for sources of loss.

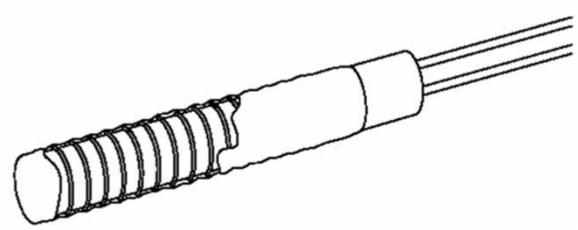
What are we going to look at?

- Contact devices
  - Varying resistance
    - Thermistors
    - RTD – Resistance temperature detectors
  - Thermocouples
  - *Silicon band-gap*
- *Non contact devices*
  - *EM emission e.g. thermal cameras*

Resistance devices - Thermistors

- Many materials display temperature dependent resistance characteristics.
- Thermistors:
  - Ceramic or polymer materials
  - NTC (negative temperature coefficient)
  - or PTC (Positive temperature coefficient)
- Have good sensitivity ($\Delta R/\Delta T$)
- Poor linearity – require compensation
- Individual devices have range ~ 200°C
- PTC devices often designed with strong non-linear characteristics to act as thermal cut-outs

Resistance devices - RTD



- RTD or Resistance Temperature Detector are similar to thermistors but utilise pure metals as the active element, e.g. platinum.
- Display a PTC characteristic and have a greater linearity in the response to temperature compared to thermistors but have lower sensitivity.
- Useable temperature range is -270°C to 600°C

Resistance devices

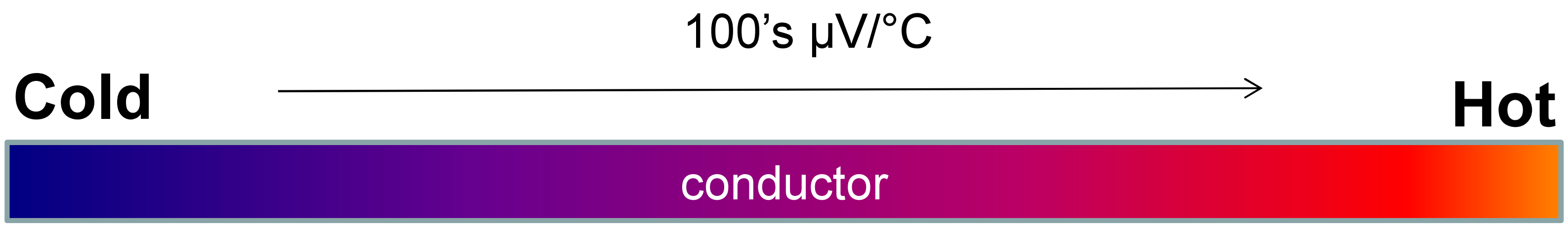
- So far we have converted temperature into resistance – we now have to turn that resistance into a voltage signal
- You can probably think of a few ways to do that already (potential divider etc.) but we will look at it in more detail in lectures to come
- In the next slides we will look at a temperature measurement technique that produces a voltage output directly…..

Thermocouples

- Thermocouples exploit the *thermoelectric* or *Seebeck* effect:

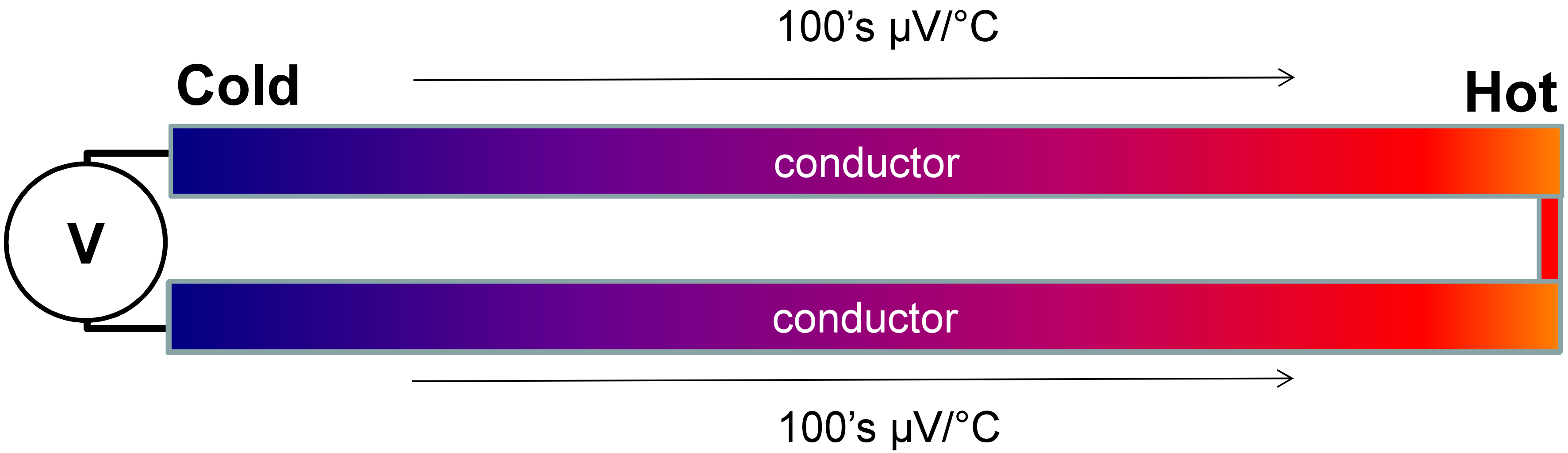
  A conductor exposed to a thermal gradient will generate a corresponding voltage gradient

- The voltage is not related to geometry, only thermal difference



Thermocouples

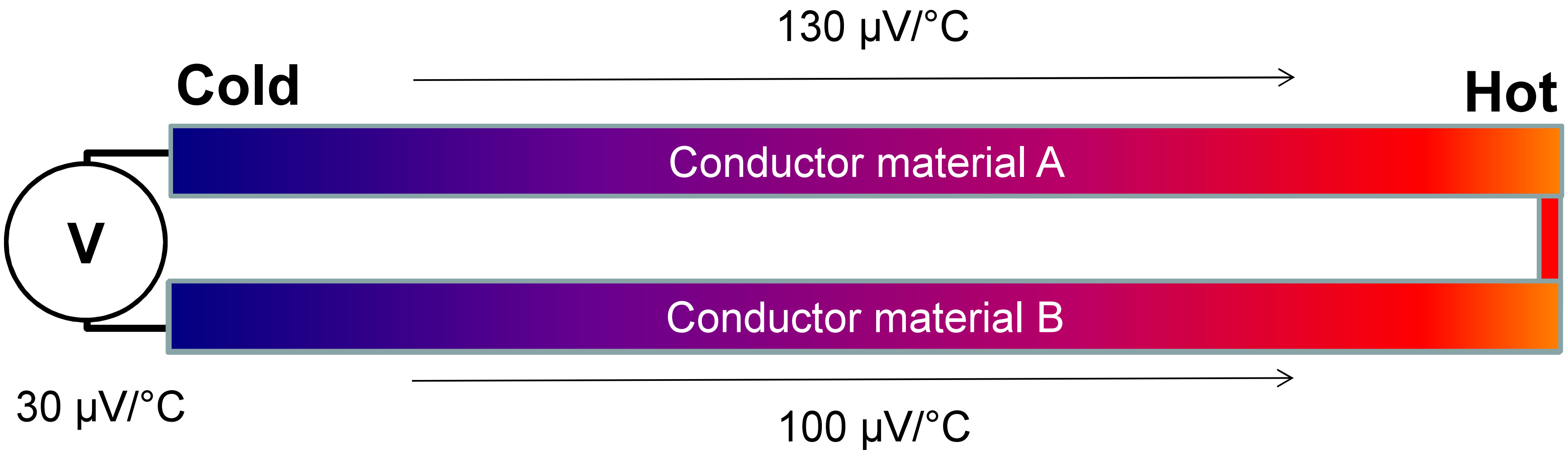
- So how do we harness this?



- Once we make electrical connections we also make a thermal connection and the 'round trip' voltage is zero!

Thermocouples

- Fortunately different materials have differing coefficients



- By carefully choosing materials we can maximise the difference

Thermocouples

K-type weld tip thermocouple with typical connector

Thermocouple connecting wire matches thermocouple to prevent introducing extra junctions

- Practical thermocouples are formed by welding the tips of wire made of the dissimilar metals together.
- The metals are kept the same over the cable run.
- Thermocouples measure relative to the cold junction. (this must be known)
- Several differing types are available, denoted by letters.

Thermocouples

- Thermocouples work well over extended temperature ranges (~2000°C) and up to high temperatures (~1700°C)
- Accuracy is less than resistance type devices, typically 1-2°C
- Thermocouples convert thermal energy into electrical energy. The effect is reversible.

Relative merits of measurement devices

	Sensitivity	Range	Linearity	cost
Thermistor	high	poor	poor	low
RTD	good	good	high	high
Thermocouple	poor	High	good	medium

Compare how they work

- Both RTD's and Thermistors produce a resistance change in response to temperature, the thermocouple produces a voltage – this is a fundamental difference we shall see again.

- Think about these processes in reverse – it doesn't make sense to think of changing an RTD's resistance to change it's temperature; but a thermocouple will work backwards – the Peltier effect.

- The thermoelectric effect (combining Peltier and Seebeck is *thermodynamically reversible*