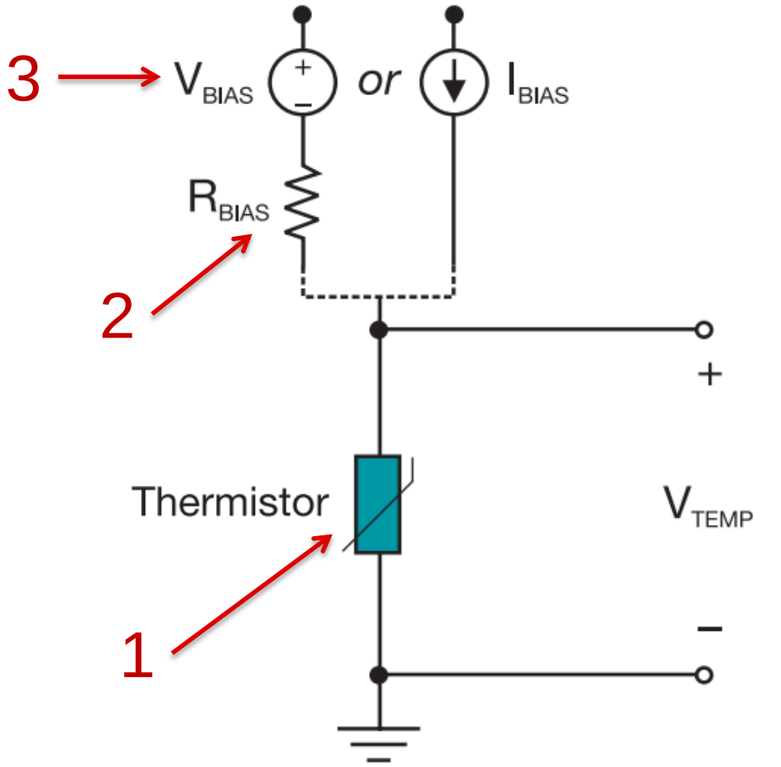
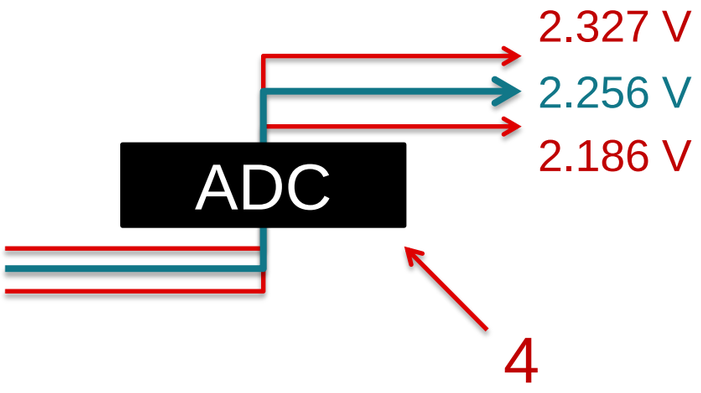
# Optimizing thermistor designs for temperature sensing

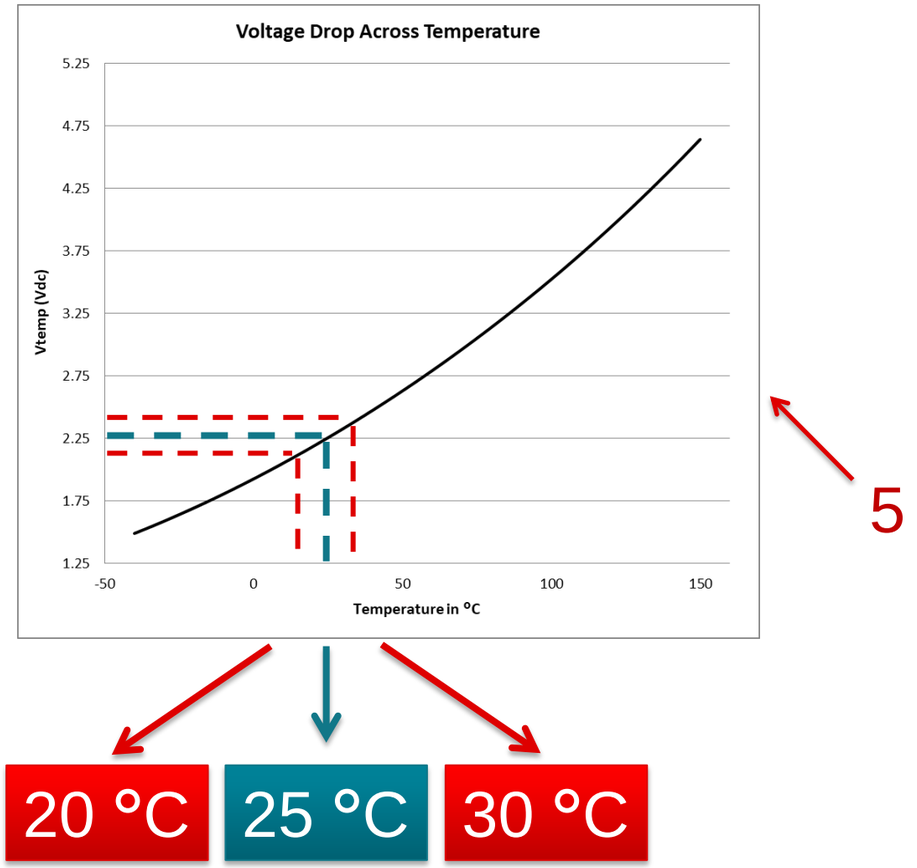
## TI Precision Labs – Thermistors

**Presented and prepared by Bryan Padilla**

# Sources of error



# Why accuracy matters

**Accuracy ↓**

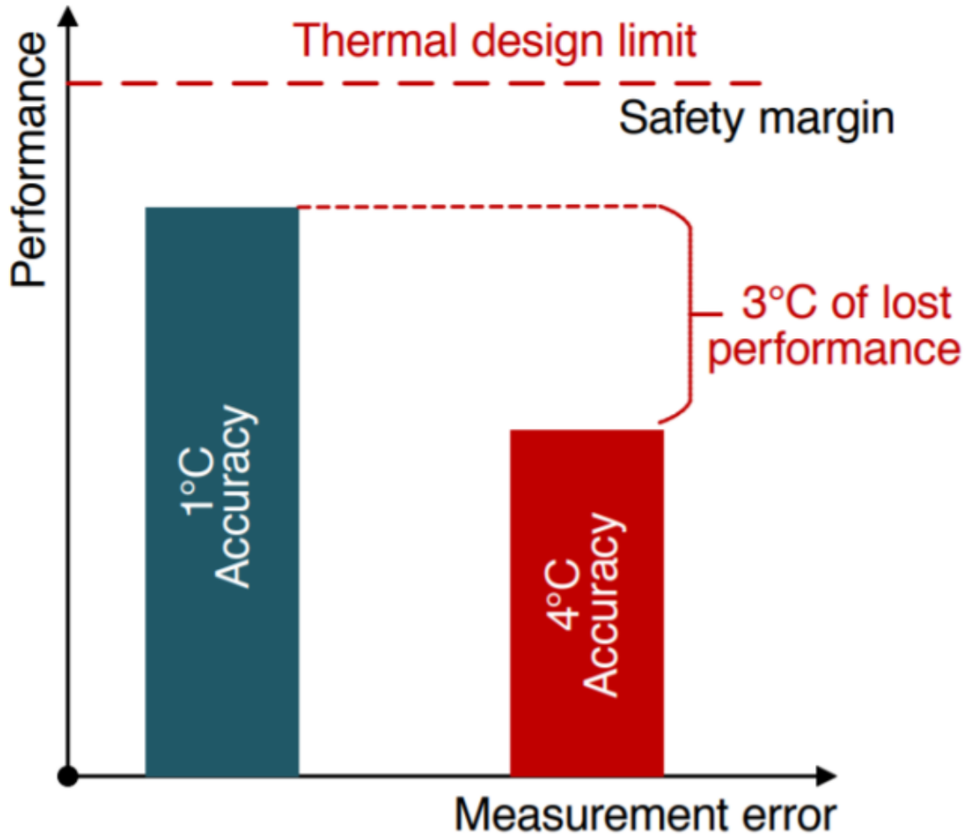
**Margin of error ↑**

**Performance ↓**

**Accuracy ↑**

**Margin of error ↓**

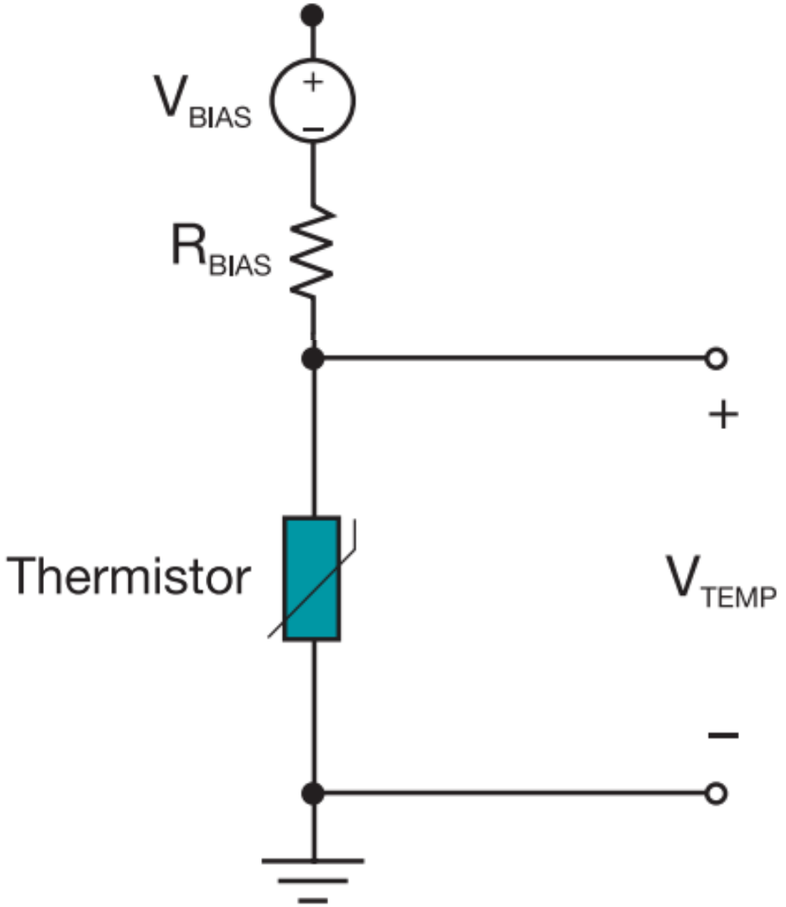
**Performance ↑**



# Methods to reduce error

1. Use precise components

| Component | Recommendations |
|---|---|
| Thermistor | Rtol ≤ 1%, Drift ≤ 1% |
| Bias resistor | Rtol ≤ 0.5%, TC ≤ 25 PPM |
| Voltage bias | $V_o$ accuracy ≤ 0.5%, TC: Low PPM |

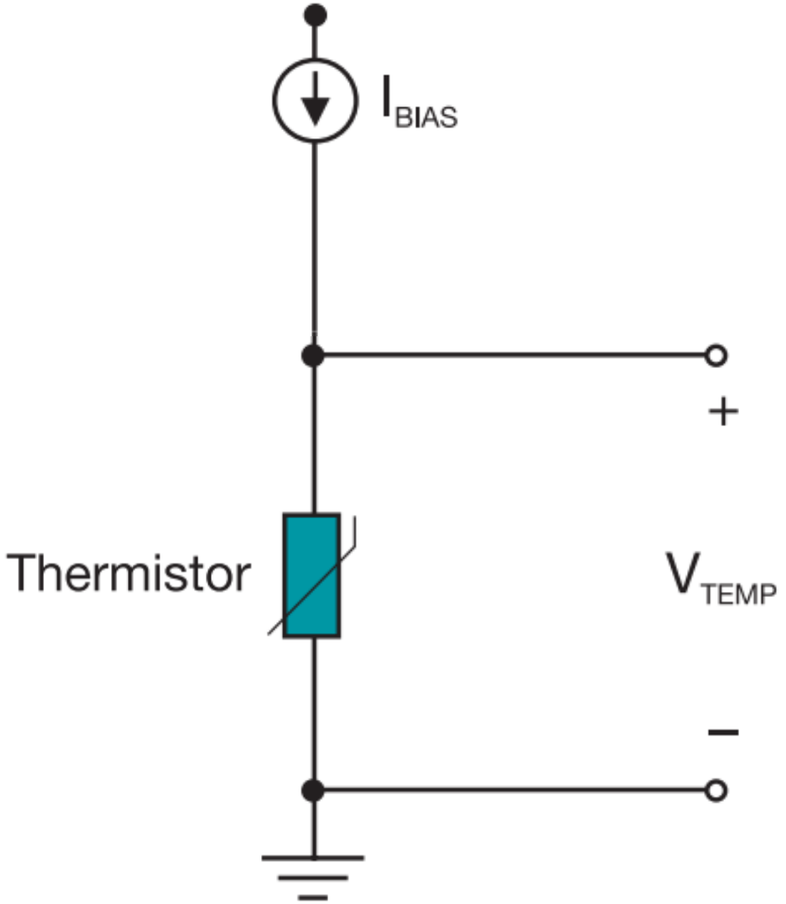


# Methods to reduce error

1. Use precise components
2. Use a current source

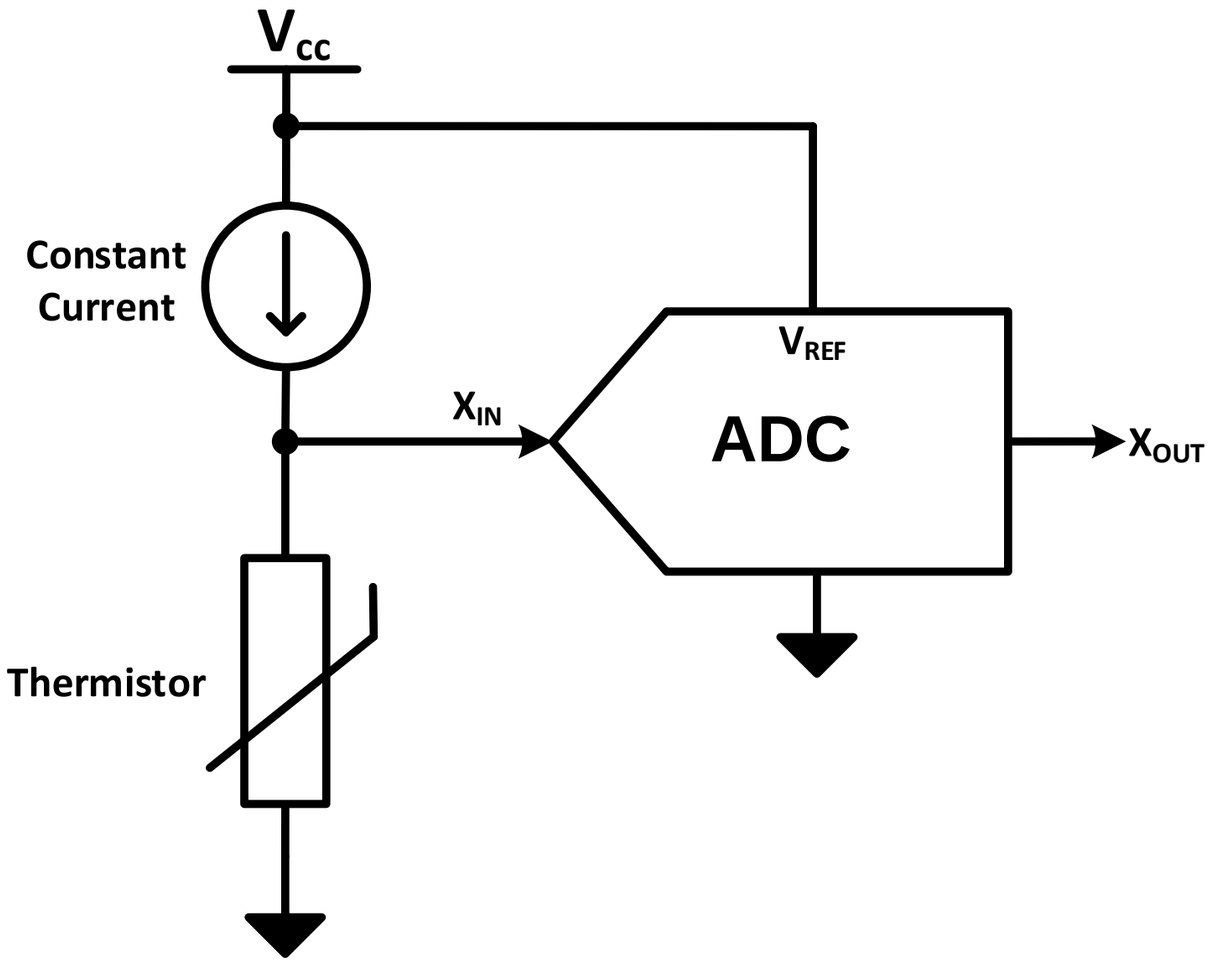
| Component | Recommendations |
|---|---|
| Thermistor | Rtol ≤ 1%, Drift ≤ 1% |
| Bias resistor | Rtol ≤ 0.5%, TC ≤ 25 PPM |
| Voltage bias | $V_o$ accuracy ≤ 0.5%, TC: Low PPM |
| Current bias | $I_o$ accuracy ≤ 0.2%, TC: Low PPM |

Eliminated



# Methods to reduce error

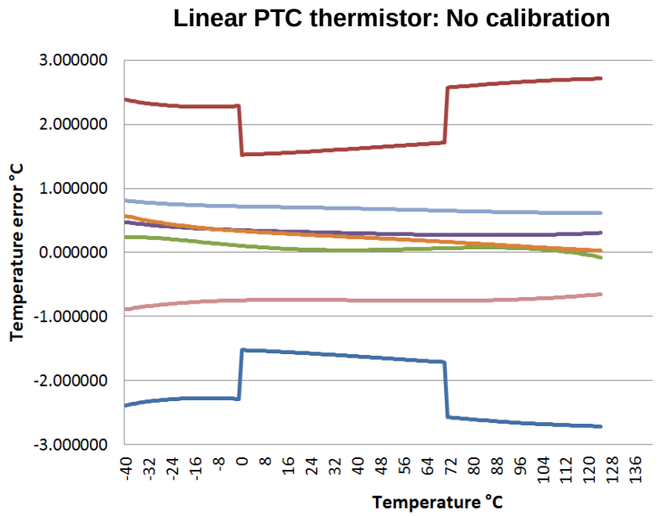
1. Use precise components
2. Use a current source
3. Use ratiometricity

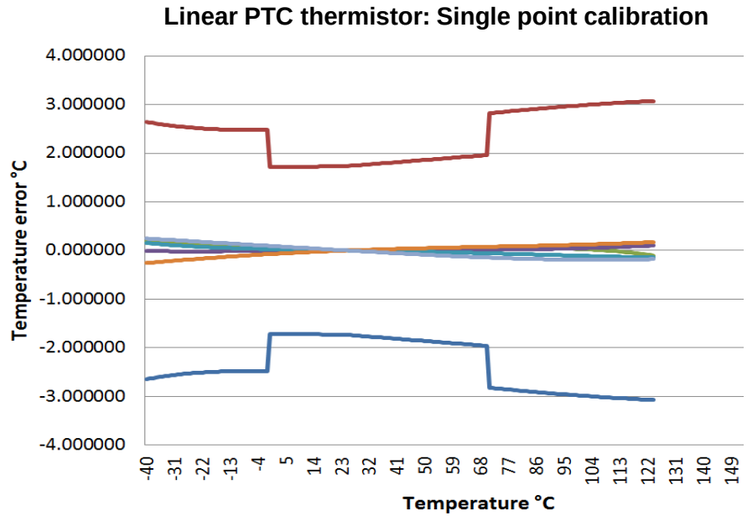



For more information, check out video 2.5

# Methods to reduce error

1. Use precise components
2. Use a current source
3. Use ratiometricity
4. Calibrate/offset your thermistor



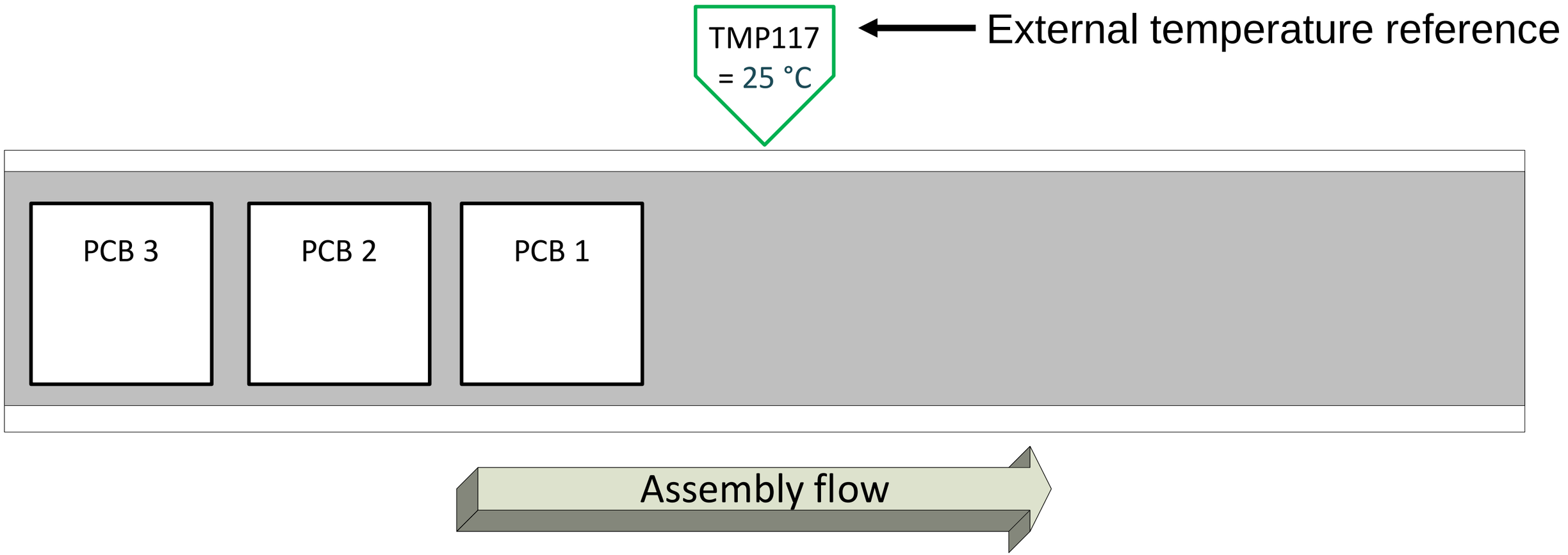




NTC: Multi-point calibration (requires temperature chamber)

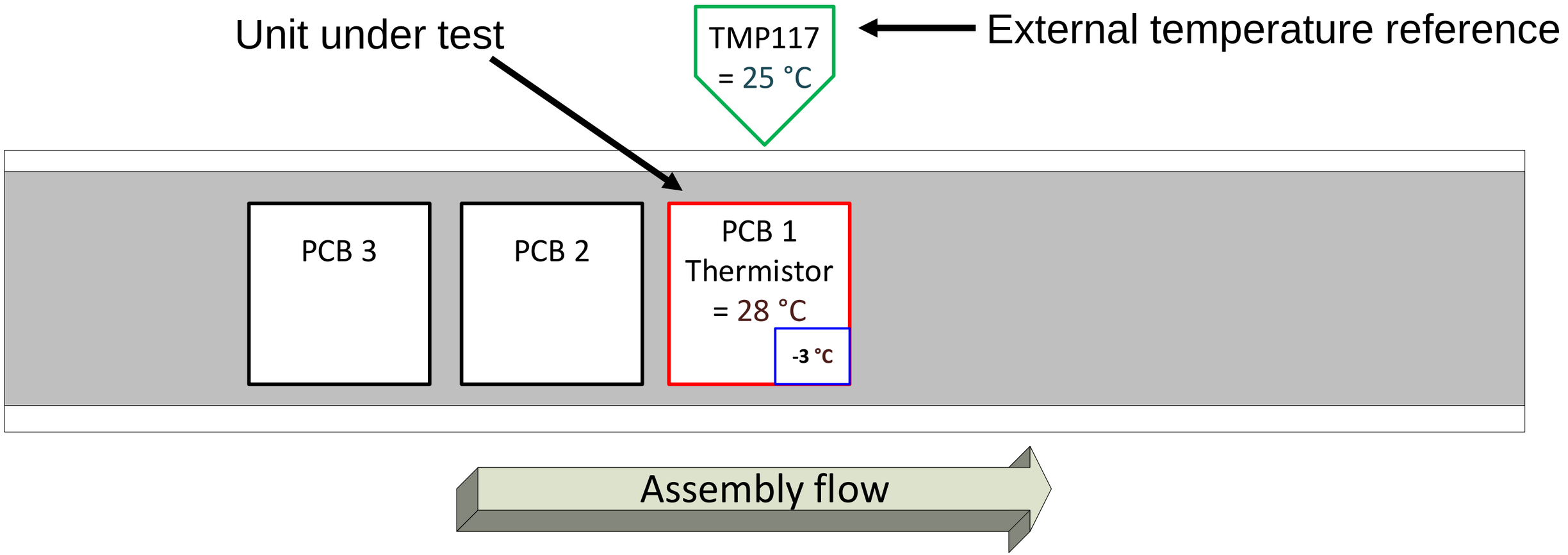
Linear PTC: Single point offset correction at room temp (no chamber)

For more information, check out video 3.1

# Single-point offset correction

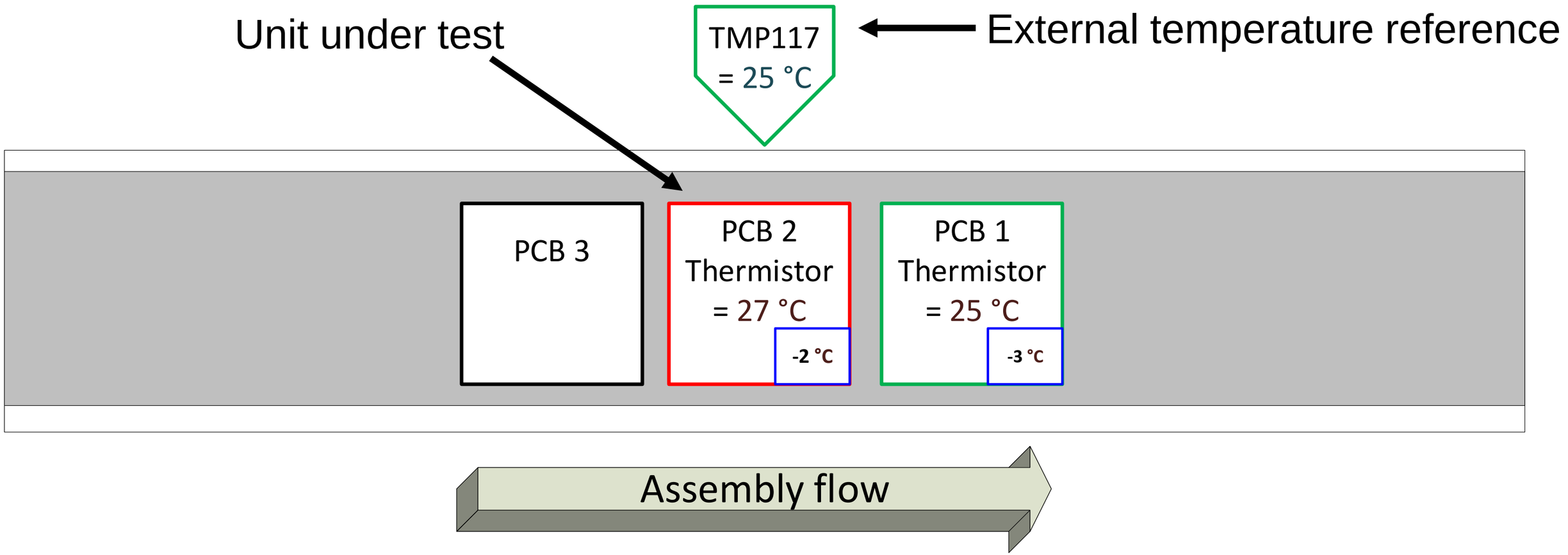


# Single-point offset correction



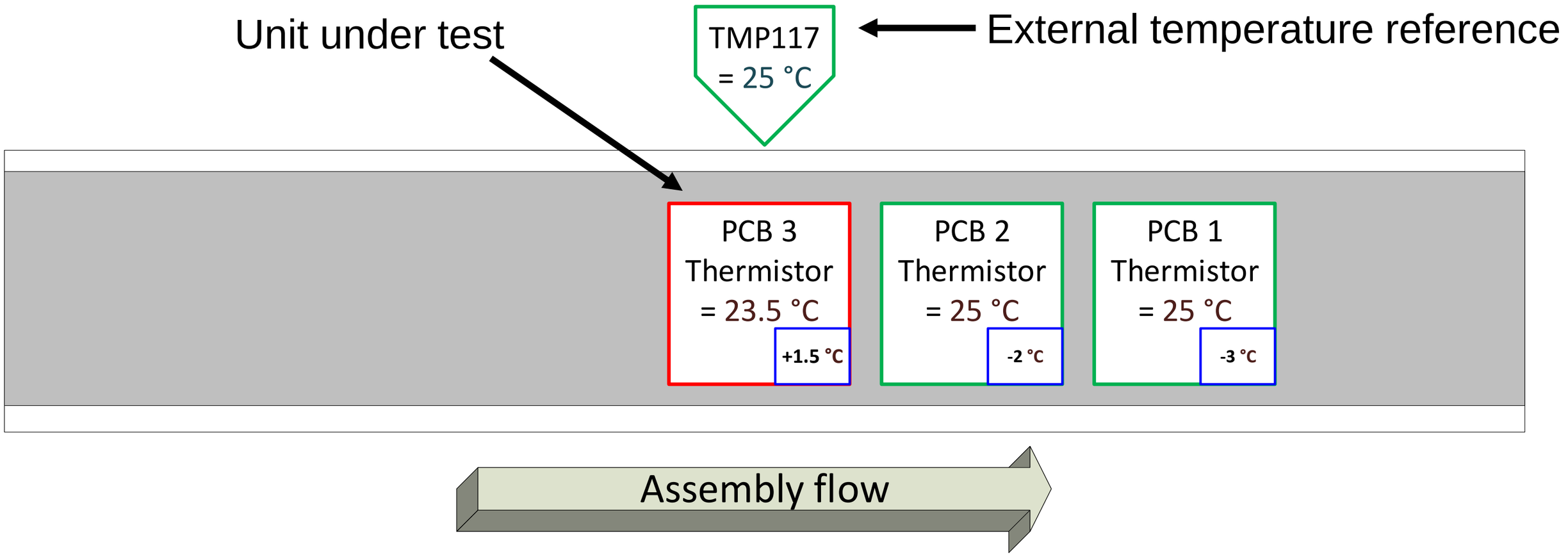

$$25 - 28 = -3$$

# Single-point offset correction



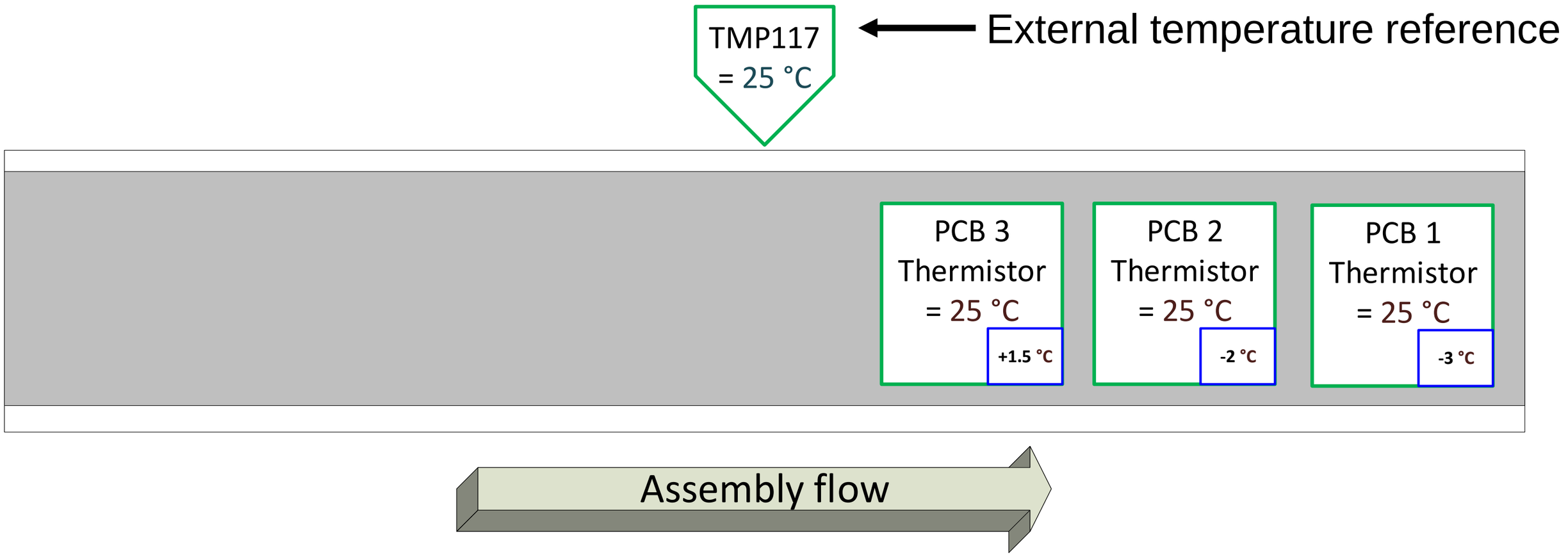

$$25 - 27 = -2$$

# Single-point offset correction




$$25 - 23.5 = +1.5$$

# Single-point offset correction



# Oversampling

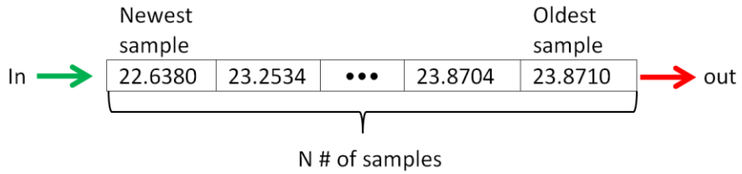
Improves resolution and SNR

| # of samples | Bit resolution |
|---|---|
| 4 | +1 |
| 8 | +2 |
| 16 | +4 |

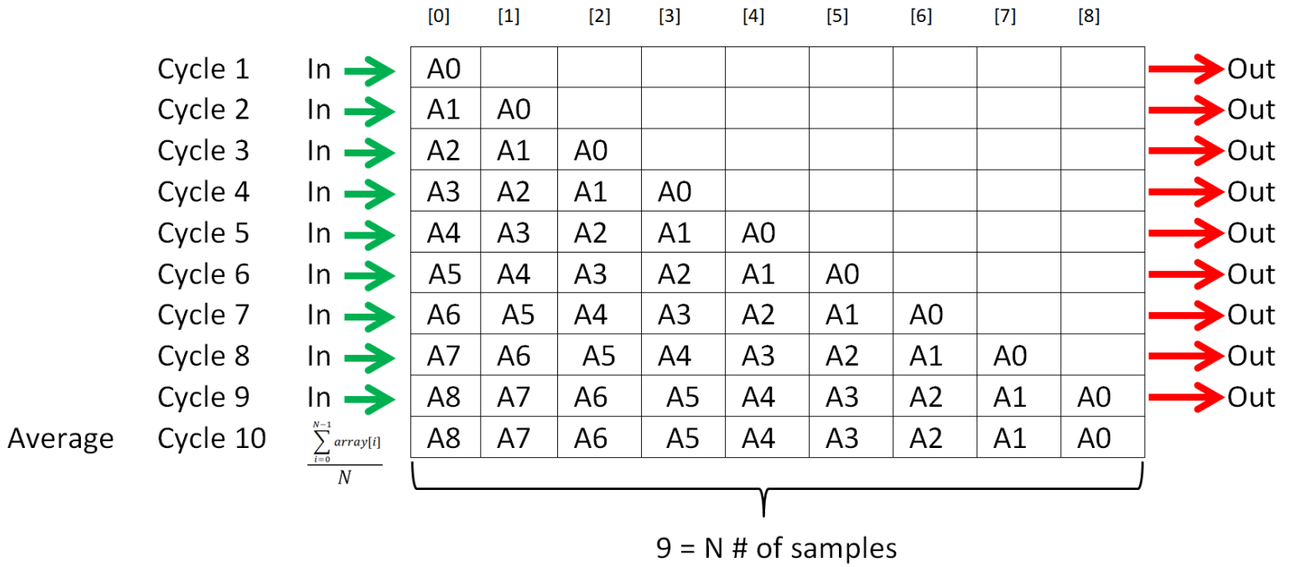
Ex:

10 bit ADC + 16x oversample = 14 effective bits of resolution

***Cannot be used in a ratiometric circuit***




$$Average = \frac{\sum_{i=0}^{N-1} array[i]}{N}$$

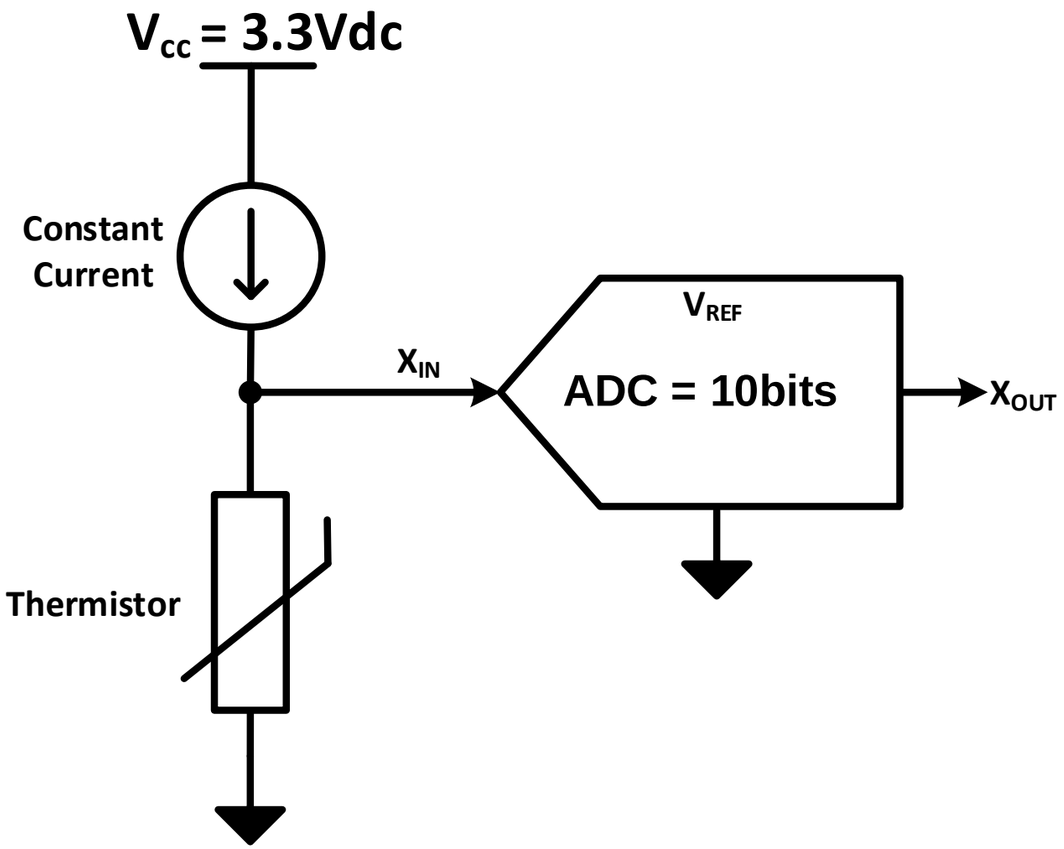


# Oversampling

$$\frac{3.3V_{dc}}{2^{10}} = 0.0032V_{dc}$$

$$0.0032V_{dc} * 4 = 0.0128V_{dc}$$

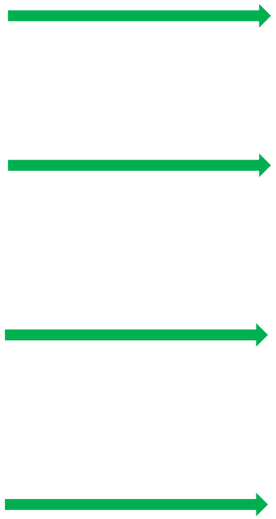
$$\pm 0.0128V_{dc} = \mathbf{0.0256}\, V_{dc}\ (p2p)$$




Recommended dithering noise

# Summary

1. **Thermistor based solutions are discrete**
   Accuracy is dependent on component tolerances
2. **Source variances**
   (Can cause error if not referenced in ADC)
3. **Component tolerance and sensitivity errors**
4. **Poor ADC bit resolution**



1. **Use precise components & minimize BOM**
   (Thermistor, resistors, voltage/current source)
2. **Implement ratiometricity**
   (Can increase total accuracies in a system)
3. **Calibrate your thermistor to get high accuracy**
4. **Oversample in software**
   (Improves resolution and SNR, cannot be done if implementing ratiometricity)

# Thank you!

**To find more thermistor resources and products visit ti.com/thermistors**