General Challenges: Designing for Accuracy

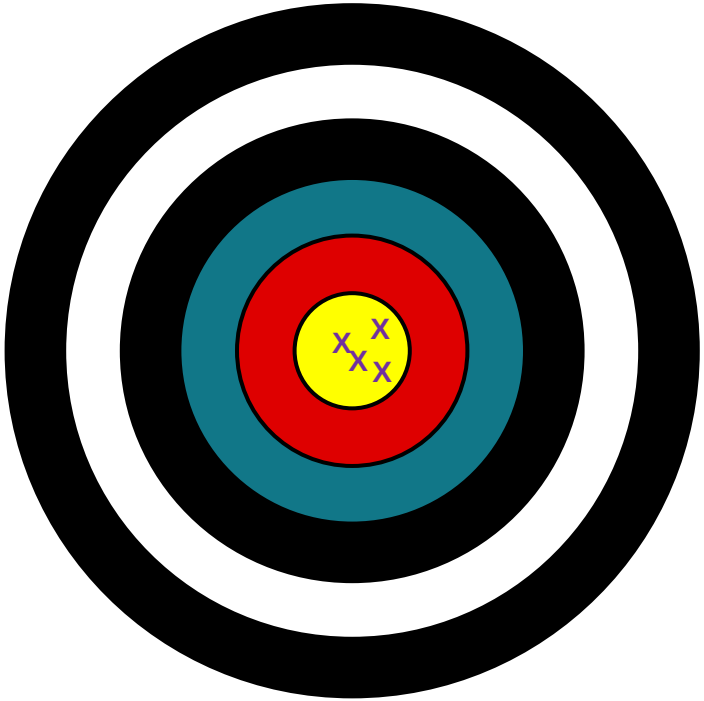
TI Precision Labs – Temperature Sensors

Presented by Daniel Mar

Outline

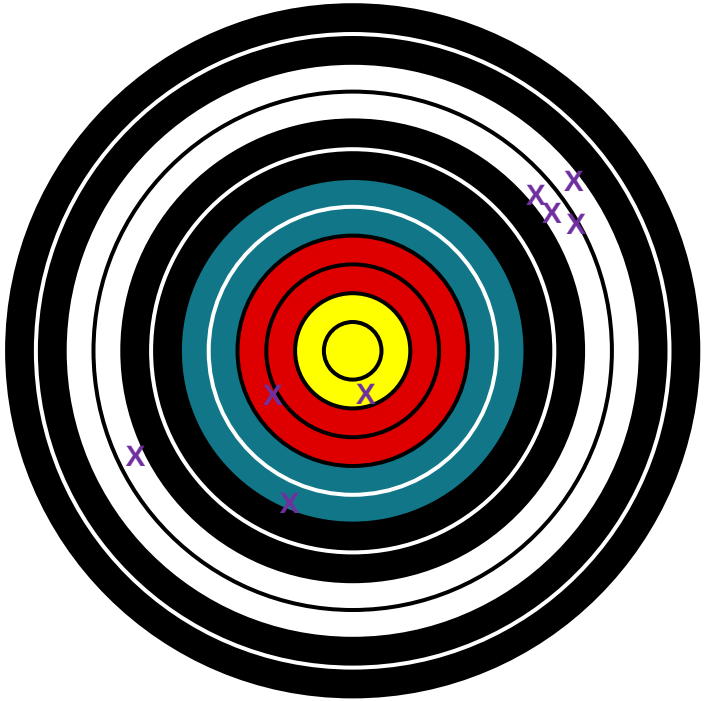
1. Understand accuracy
2. NTC Accuracy:
   - Understanding Tolerance and Beta
   - Additional error sources
3. IC Temperature Sensors Accuracy
4. Designing for accuracy
   - Example: Measuring Ambient Air Temperature

Accuracy



Accuracy

VS



Resolution

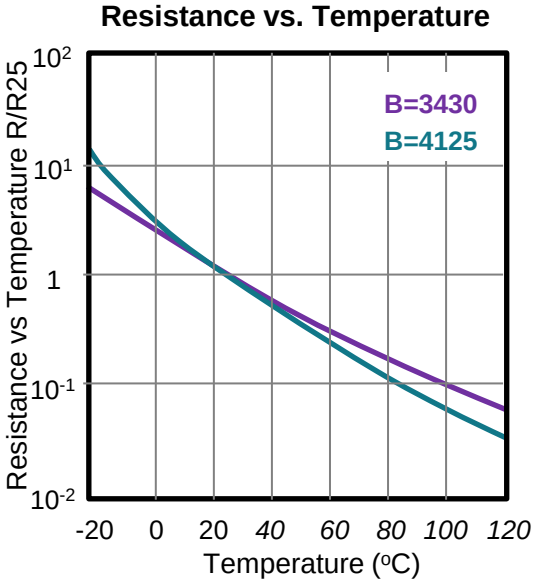
NTC Thermistor Accuracy

Parameter	Value
Resistance value at 25 °C	10,000 Ohms
Tolerance on R25-value	1%
B25/85-value	3430 to 4125 K

1% tolerance $\neq$ 1% measurement accuracy

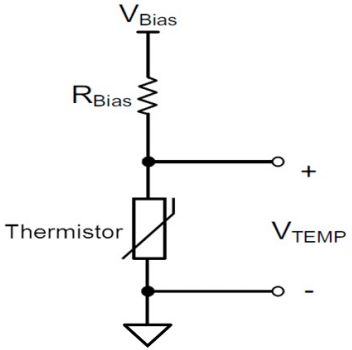
1% tolerance $=$ 1% nominal resistance (at 25°C)

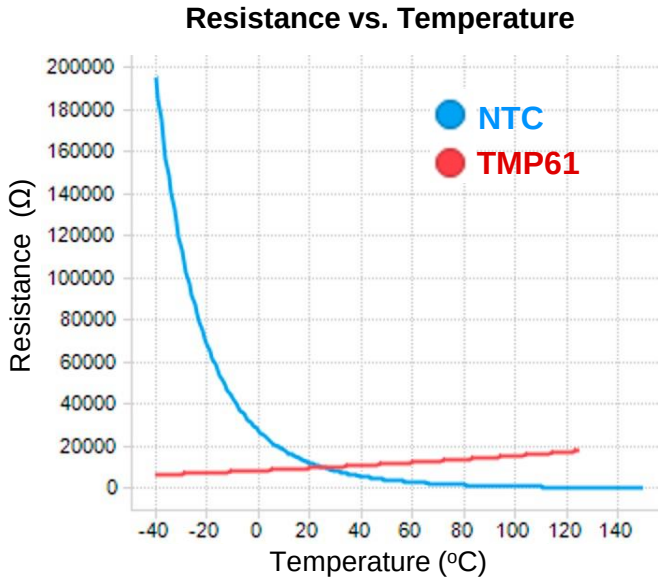
Beta describes the shape of the thermistors curve
Variability in beta will drive additional inaccuracy away from 25°C



Additional Thermistor Error Sources

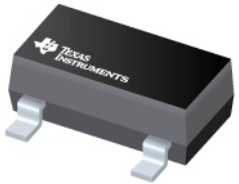
- Thermistor isn't the only component
  - R_{Bias} : Tolerance & Drift
  - V_{Bias}: Noise
  - ADC: LSB
  - ADC: VREF
  - Amplifier (optional)
  - Vcc:

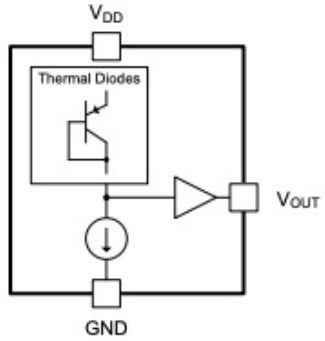




- Linearization error
- Quantization error
- Self-heating

IC Temperature Sensors

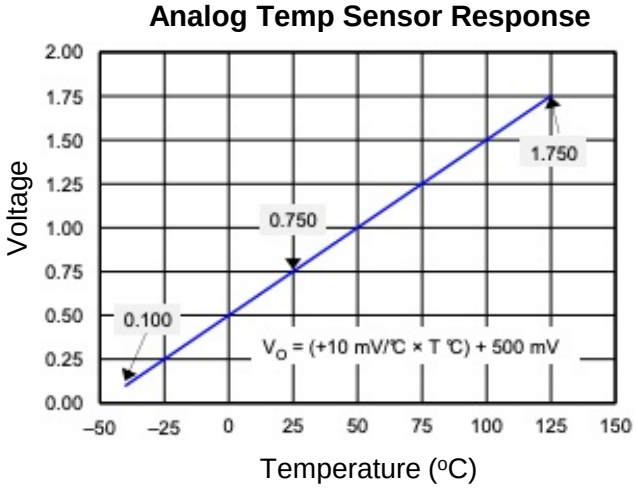




- Defined Accuracy:

Accuracy	Typical	Max
0°C to 70°C	0.5°C	1°C
-40°C to 150°C	0.5°C	2°C

  - Typical: Expected accuracy
  - Max: Worse case accuracy
- Dramatically reduces linearization and quantization error compared to NTC
- No external components contributing to error
  - Except for ADC if selecting analog output temp sensor
- Minimal self-heating (<5uW with integrated ADC)



Optimizing Layout:

Crucial to achieving an accurate measurement and reducing thermal response time

1. **Measurement Objective**
   - Layout according to objective (ambient air, another component on PCB, body temperature…)
2. **Understand the thermal pathways:**
   - Heat gain/loss to other components
   - Heat gain/loss to surrounding air and airflow around the sensor
   - Radiative Heat Sources
3. **Reduce thermal resistance** to objective and increase thermal resistance to other sources
   - Placing sensor closer to the target, and away from other heat sources
   - Adding or widening metal traces to improve thermal connection
4. **Reduce thermal mass**
   - Improves thermal response time: avoiding lag between the target's temperature and the sensor reaching reaching equilibrium.

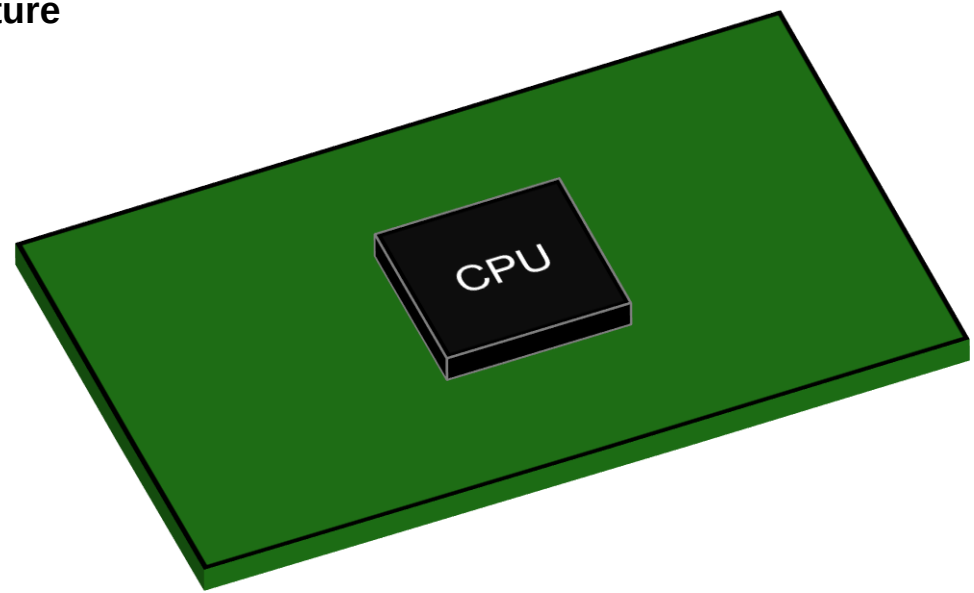
Example

Measurement Objective: **Ambient Air Temperature**

Understand the thermal pathways:

Thermal resistance

Thermal mass



Example

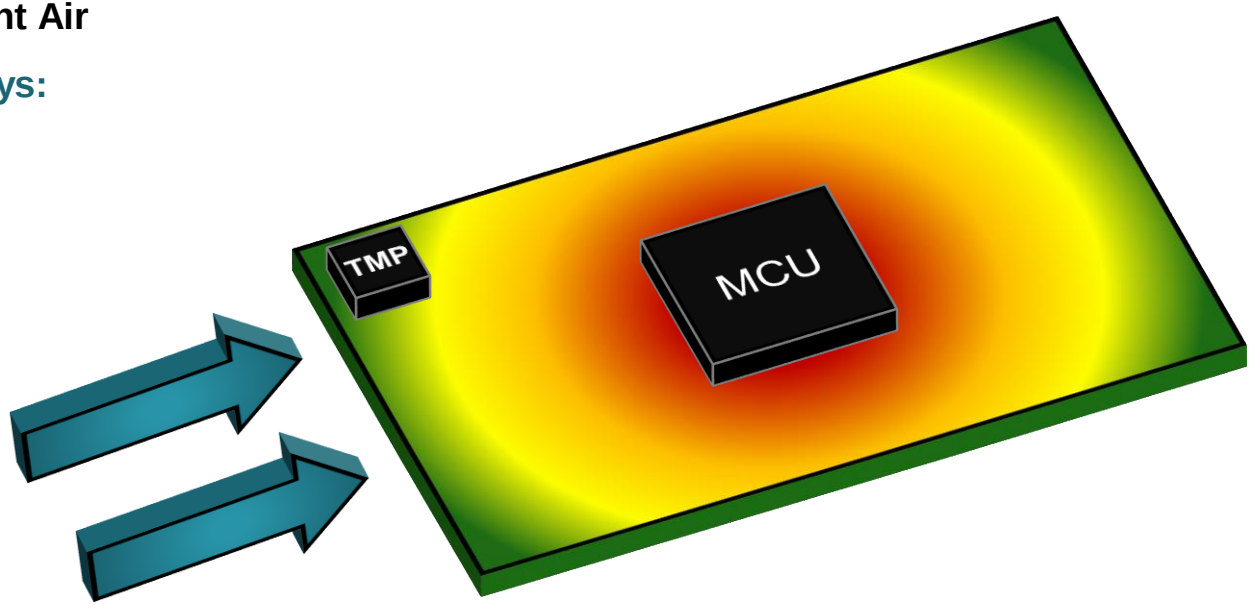
Measurement Objective: **Ambient Air**

Understand the thermal pathways:

- **Heat Sources**
- **Air Flow**

Thermal resistance

Thermal mass



Example

Measurement Objective: Ambient Air

Understand the thermal pathways:

- Heat Sources
- Air Flow

Thermal resistance

- Conduction thru traces (narrow)
- Conduction thru PCB

Thermal mass

- Minimize mass of sensor and PCB