Sensors and Actuators

Introduction to sensors

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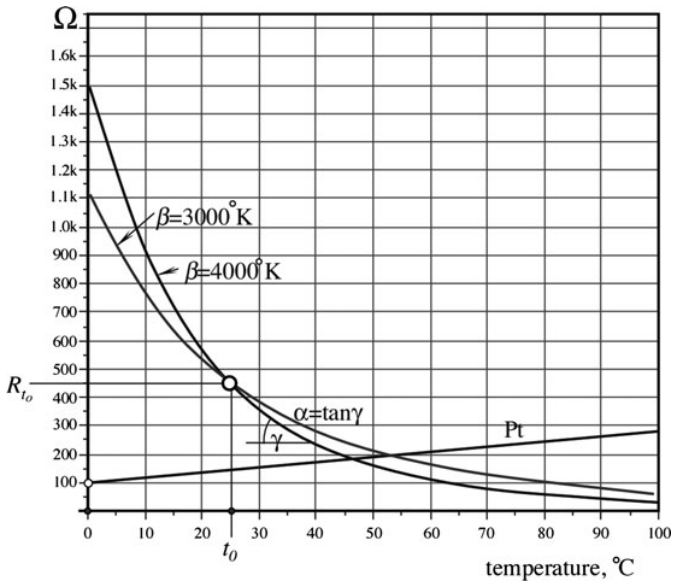
SENSOR CHARACTERISTICS

(Chapter 2)

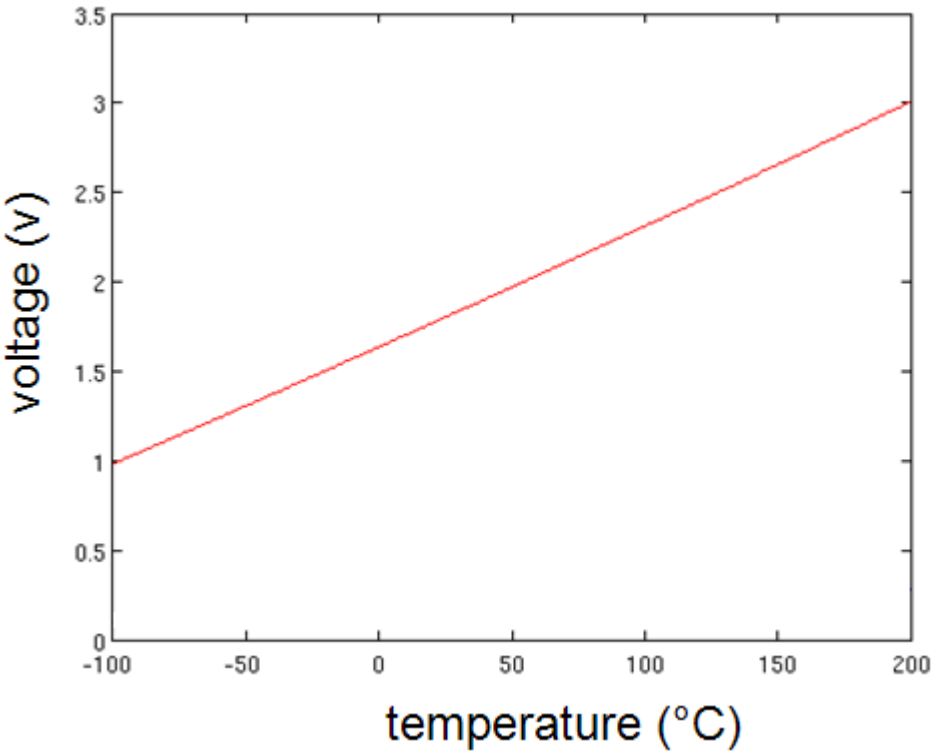
Resistance

- resistance of a material is defined as $R = \frac{V}{i}$
- resistance depends on geometrical factors $R = \rho \frac{l}{a}$
  - length of wire (l)
  - cross-sectional area (a)
- resistance depends on temperature $R = \rho \frac{l}{a} = \frac{m}{ne^2\tau} \frac{l}{a}$
  - number of free electrons (n)
  - mean time between collisions (τ)
- resistor as temperature sensor
  - some types have almost linear relation between temperature t (°C) and resistance R (Ω)
  - example: platinum (PT100) sensor

$$R_t \approx R_0\left(1 + 39.08 \times 10^{-4} t\right)\Omega$$



Basic characteristics

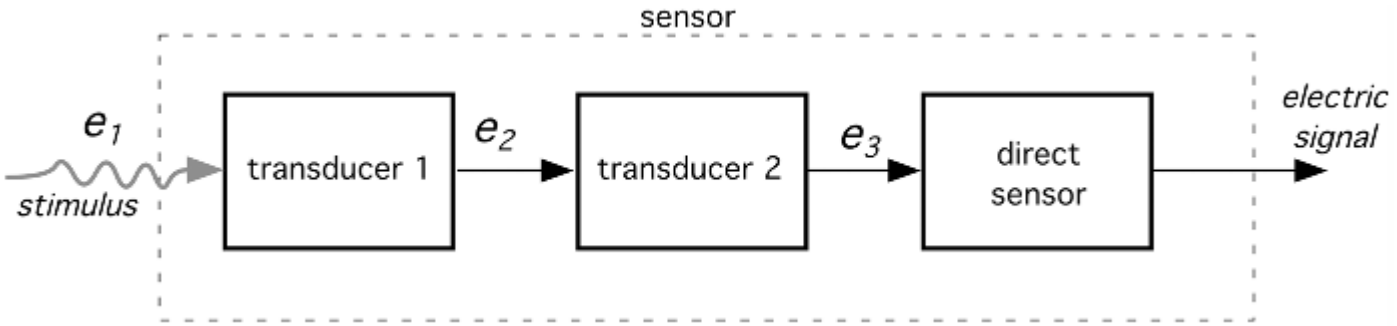


PT100 sensor
input full scale: +200°C
output full scale: 3V
range: -100°C to +200°C
span: 300°C, 2V

- full scale input: maximal input value
- full scale output: output value at maximal input value
- range: lowest and highest values of the input stimulus
- span: the arithmetic difference between the highest and lowest values of the input or output

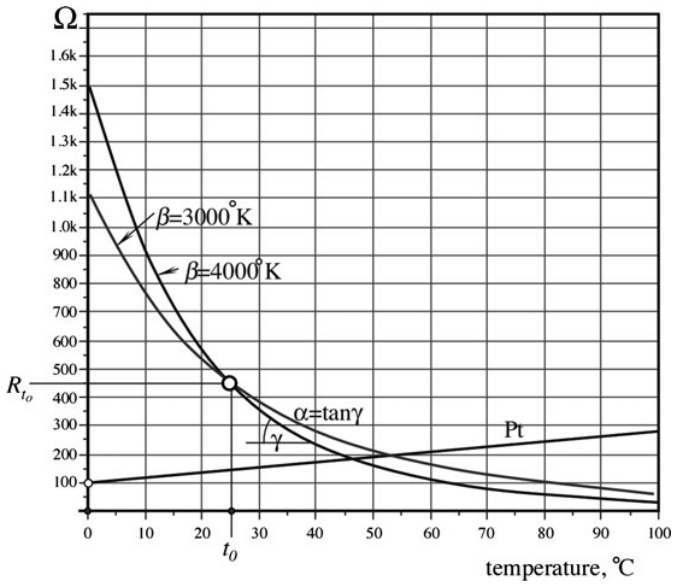
Transfer function

- sensors translates input signal to electrical signal



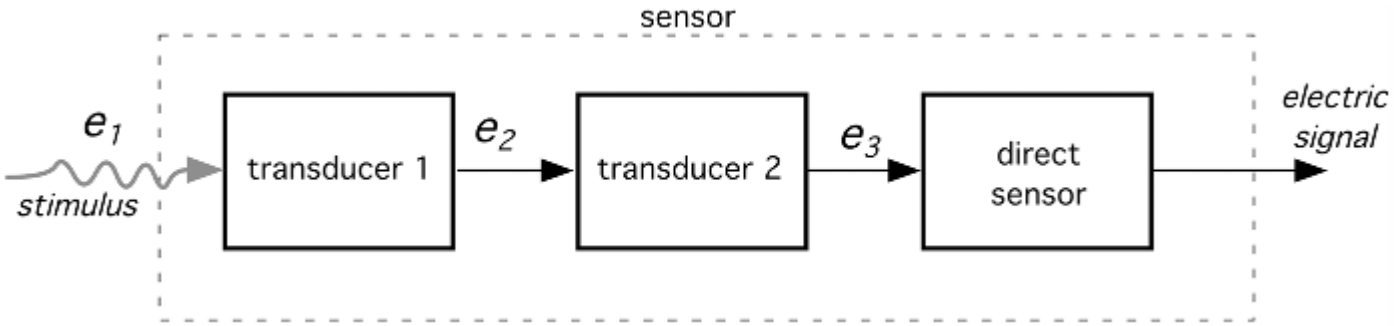
- transfer function gives relation between input and output signal

resistor by itself is not a useful sensor (**why?)**

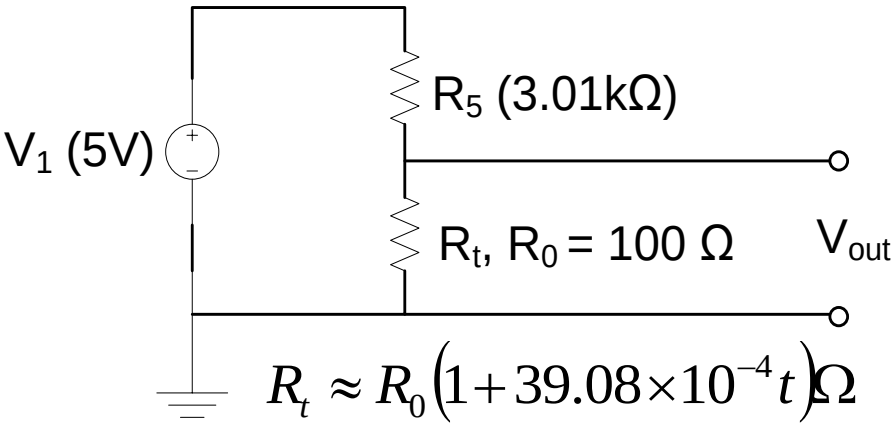


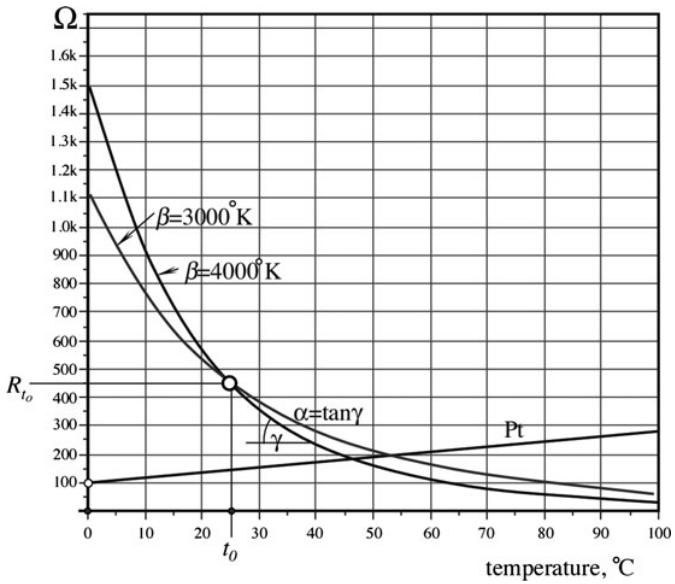
Transfer function

- sensors translates input signal to electrical signal



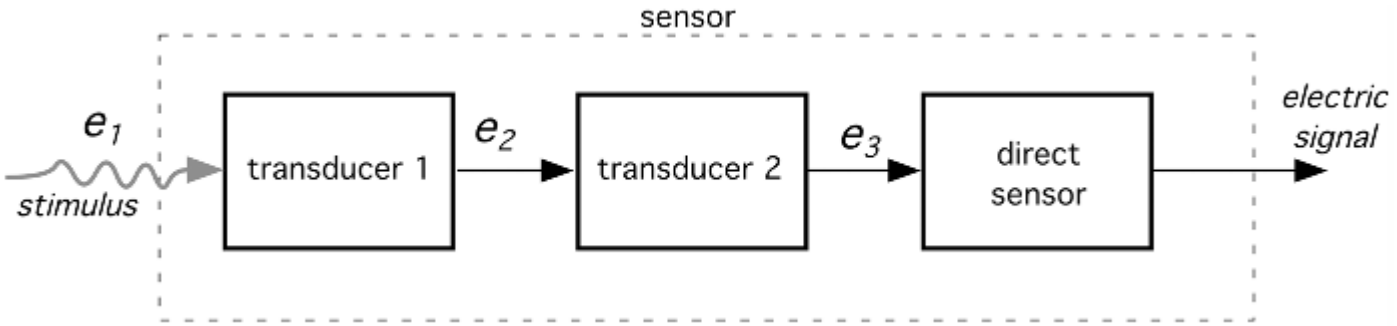
- transfer function gives relation between input and output signal



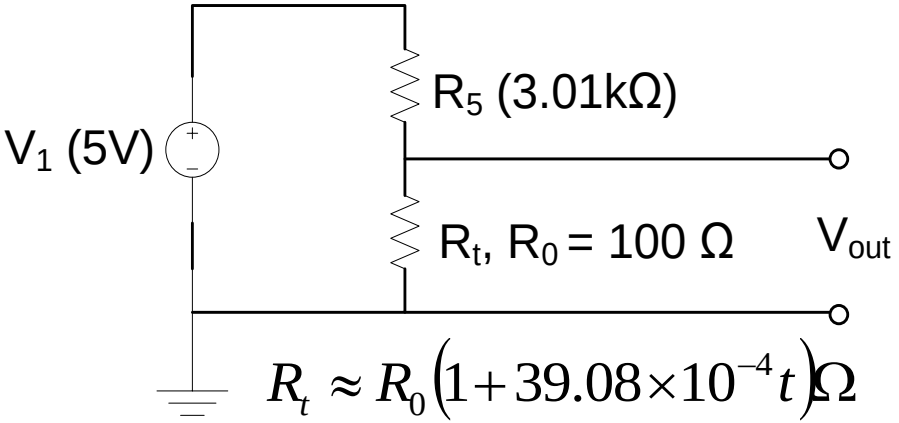


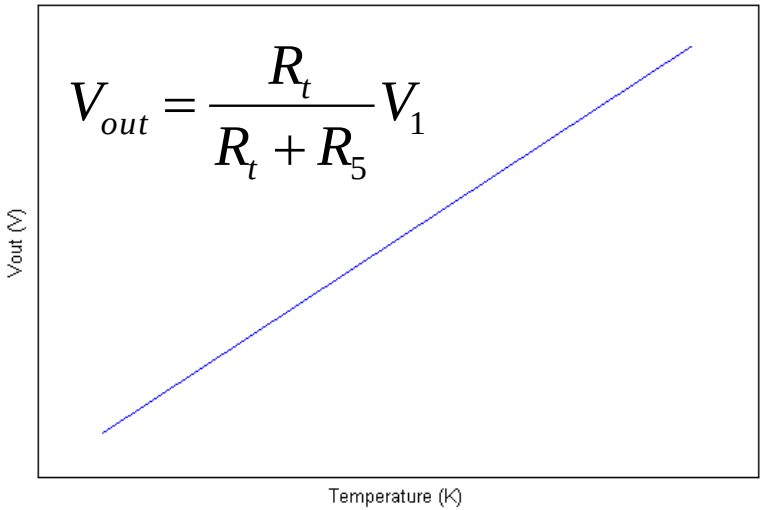
Transfer function

- sensors translates input signal to electrical signal



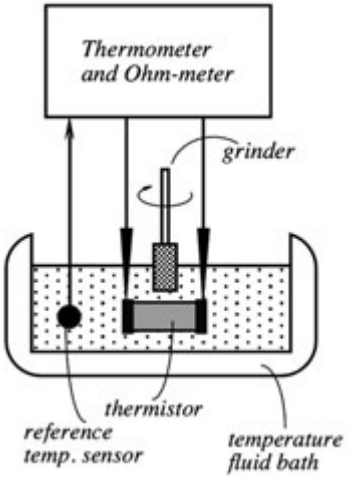
- transfer function gives relation between input and output signal

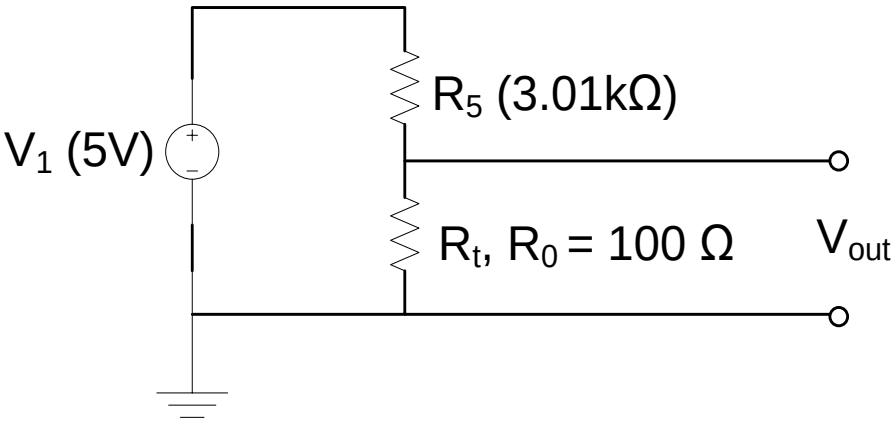


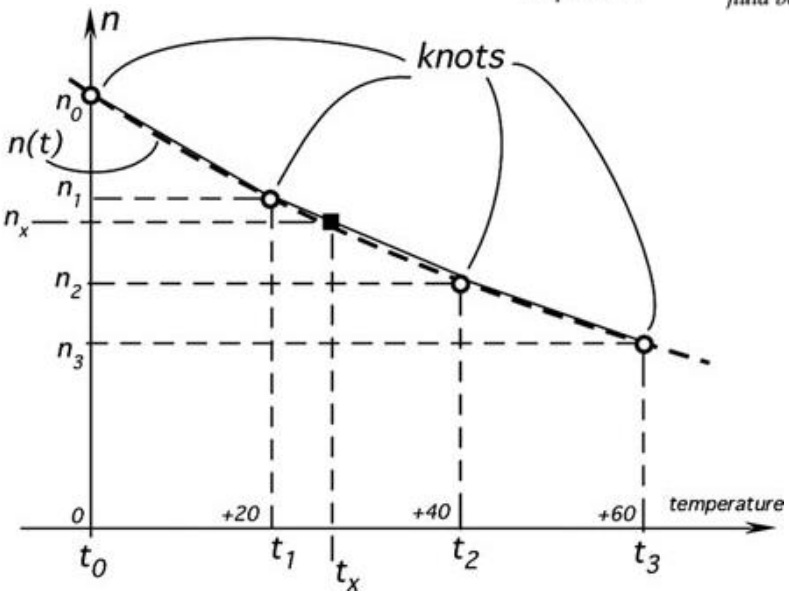


Transfer function

- **how to get the transfer function?**
- calibration: experimental determine the transfer function
- calibration procedure
  - put sensor in known circuit
  - measure V_{out} at know temperature
  - repeat measurement at different temperatures
  - create transfer function



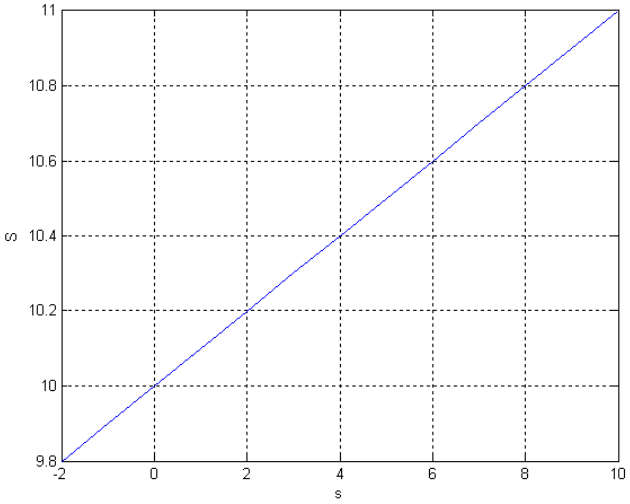




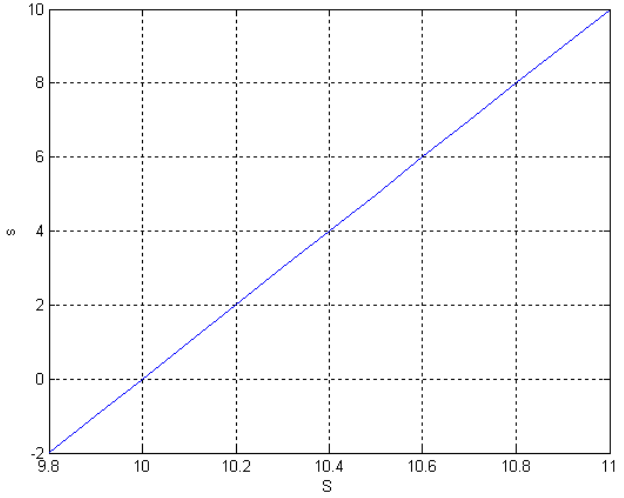
Transfer function

- Linear transfer function: $S = a + b \cdot s$

$S = 10 + 0.1 \cdot s$



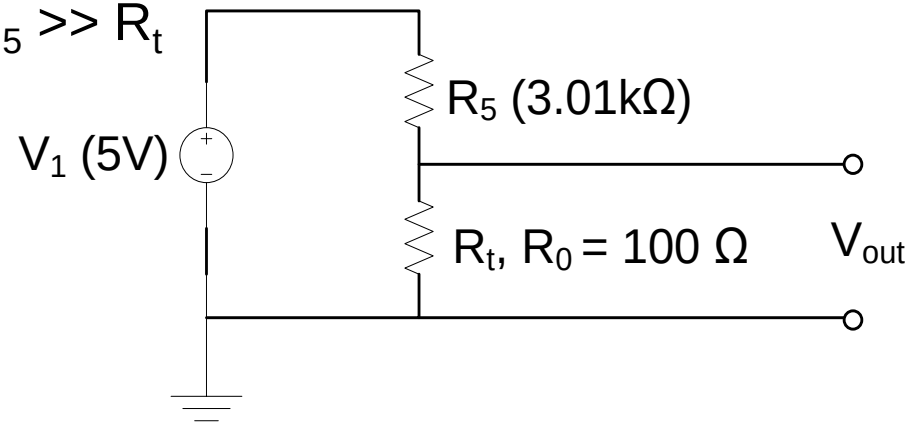
inverse: $s = (S - 10) / 0.1$



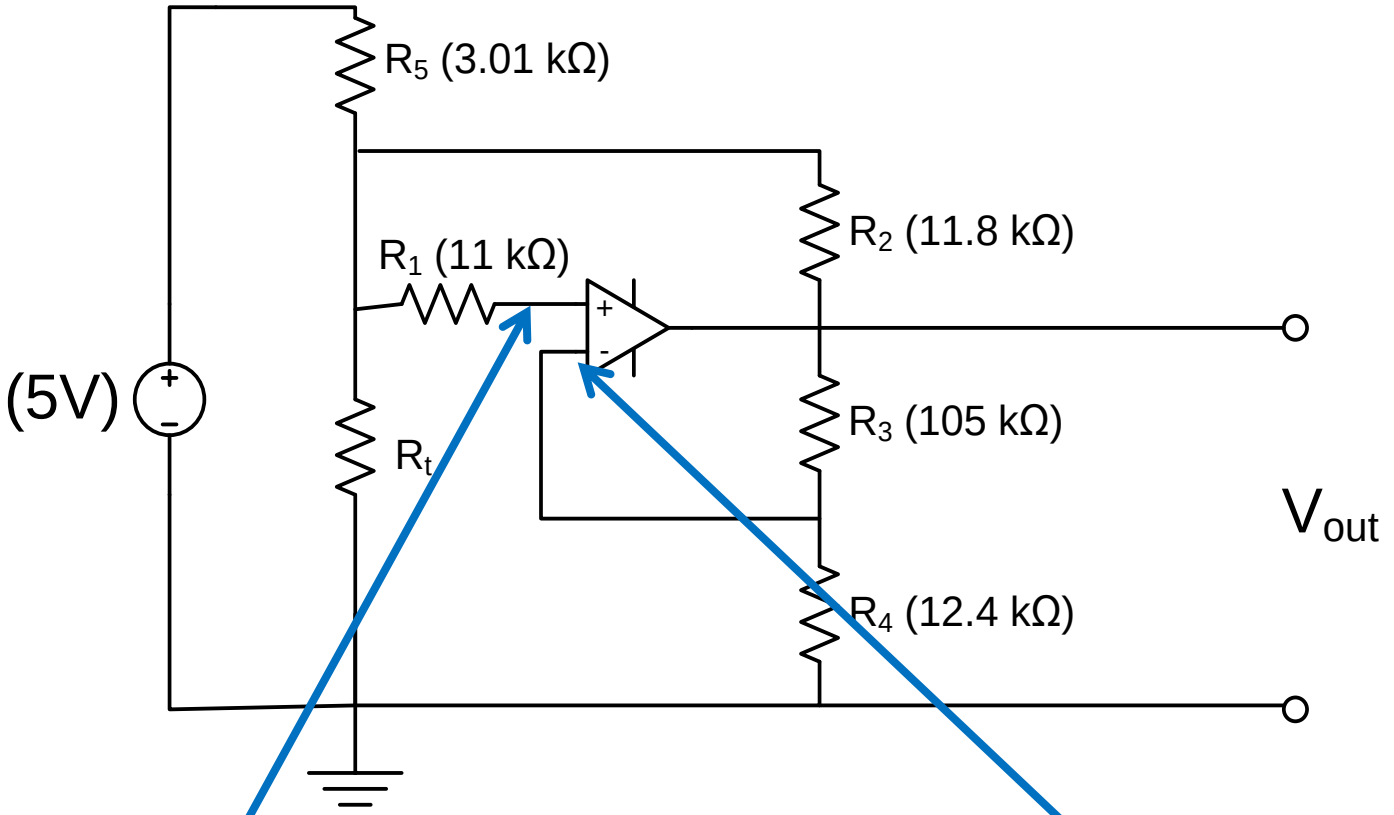
- sensitivity is the change in output due to a small change in input
- offset is the value of the output when the input is zero
- sensors with a linear transfer functions are preferred (**why?**)
  - simple calibration (few unknown parameters)
  - constant sensitivity (simple processing)
  - simple inverse function (simple processing)

Sensitivity

- sensitivity of many sensors is very low
  - PT100 has sensitivity of 0.39 Ω/K
  - V_{out} = 161 mV when T = 273 K, V_{out} = 173 mV when T = 293 K
  - **what is the sensitivity in mV/K?**
    - 0.6 mV/K
  - **what limits the sensitivity?**
    - resistor R_5
  - **how can we increase the sensitivity?**
    - use smaller R_5, but this leads to problems
    - increasing current, leads to self-heating
    - output only linear when $R_5 >> R_t$
- signal processing needed to amplify the sensor output



Signal processing

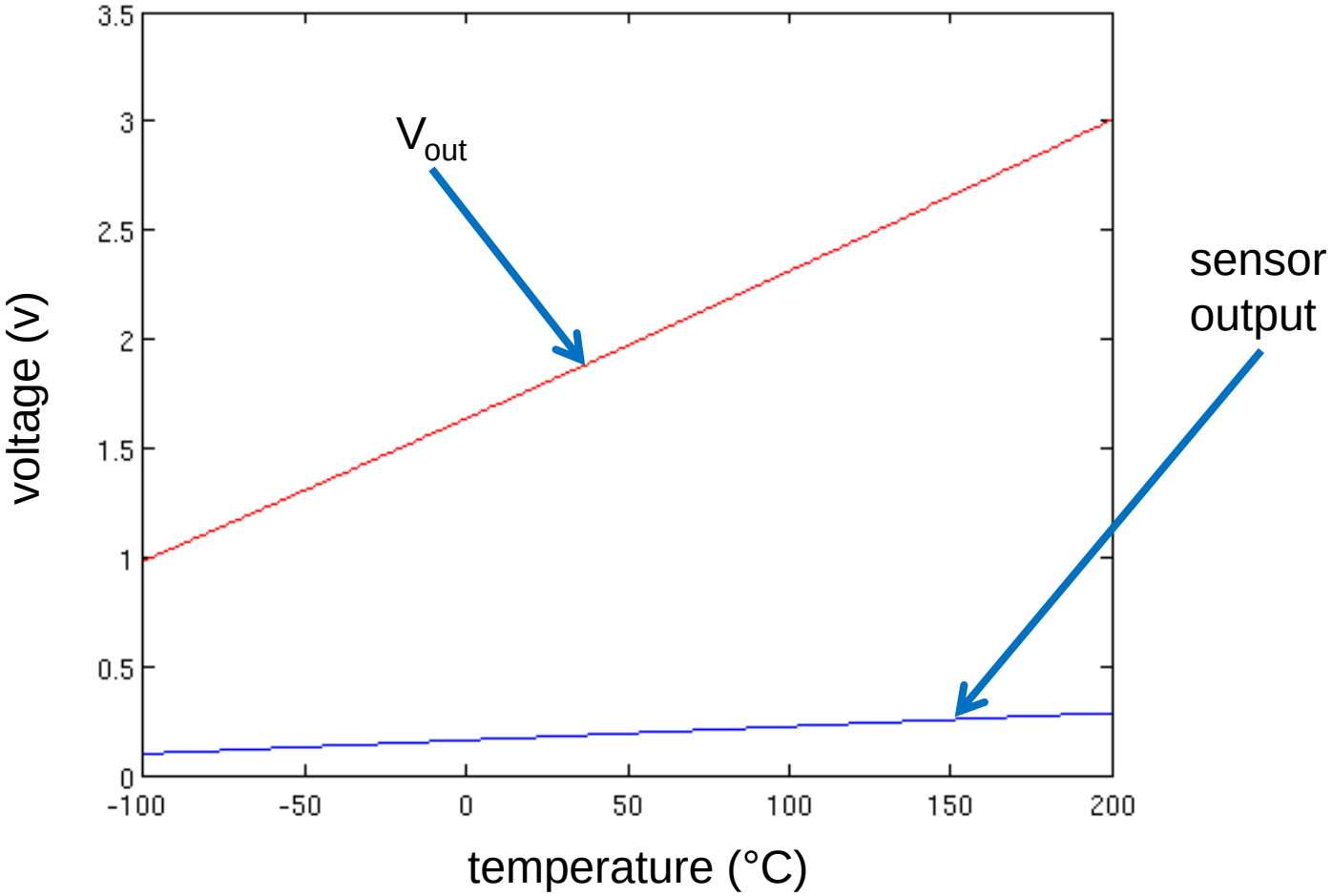


$$V_+ = V_{out}\frac{R_5 /\!/ R_t}{R_5 /\!/ R_t + R_2} + V_1\frac{R_2 /\!/ R_t}{R_2 /\!/ R_t + R_5}$$

$$V_- = V_{out}\frac{R_4}{R_3 + R_4}$$

$$V_- = V_+ \Rightarrow V_{out} = \frac{V_1\dfrac{R_2 /\!/ R_t}{R_2 /\!/ R_t + R_5}}{\dfrac{R_4}{R_4 + R_3} - \dfrac{R_5 /\!/ R_t}{R_5 /\!/ R_t + R_2}}$$

Signal processing



- sensitivity increased from 0.63mV/°C to 6.67mV/°C
- non-linearity has also been decreased...