Measurement Instruments

Please do the following exercises individually.

Characteristics of a Sensor

A sensor produces the following outputs:

x	10	20	30	40	50	60	70	80	90
y	12.41	20.75	28.77	33.95	37.49	41.1	43.92	45.47	46.87

It has an expected live span of five years, costs 35.00 € and has a maintenance cost of 5.00 € per year. Please determine the following characteristics:

- The output of the sensor if the input is 43.
- The sensitivity of the sensor at 20 and 60.
- The annual costs of the sensor.

Measurement Chain

A sensor produces an output voltage of 41.1 mV. It shall be connected with a 10-bit ADC with a reference voltage of 5V. Please specify the following characteristics of the measurement chain:

- An adequate gain for the measurement amplifier
- The type of amplifier used
- The resistance of R_1 and R_2
- The output of the ADC

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It has an expected live span of five years, costs 35.00 € and has a maintenance cost of 5.00 € per year. Please determine the following characteristics:

- The output of the sensor if the input is 43.

  $$\mathrm{f}(x) = y_0 + \frac{y_1 - y_0}{x_1 - x_0}(x - x_0) = 33.95 + \frac{37.49 - 33.95}{50 - 40}(43 - 40) = 35.01$$

- The sensitivity of the sensor between 20 and 30 and between 60 and 70. Does the sensitivity increase or decrease?

  $$S_1 = \frac{y_1 - y_0}{x_1 - x_0} = \frac{28.77 - 20.75}{30 - 20} = 0.80; \quad S_1 = \frac{y_1 - y_0}{x_1 - x_0} = \frac{43.92 - 41.10}{70 - 60} = 0.28$$

  The sensitivity hence decreases.

- The annual costs of the sensor.

  $$Cost_{Year} = \frac{Cost_{Purchase} + Cost_{Maitenance}}{Expected\ Live\ Time} = \frac{35\ € + 5 \cdot 5\ €}{5} = 12\ €$$

  The annual costs of the sensor is 12 € per year.

Measurement Chain

A sensor produces an output voltage of 41.1 mV. It shall be connected with a 10-bit ADC with a reference voltage of 5V. Please specify the following characteristics of the measurement chain:

- An adequate gain for the measurement amplifier
  Reference voltage: 5V → 4.11 V is an adequate sensor output → gain should be 100
- The type of amplifier used
  Sensor output is positive; ADC input is positive → a non-inverting amplifier is required
- The resistance of R_1 and R_2
  See NWES Module 5.3.1

  $$A_{CL} = 1 + \frac{R_2}{R_1} \rightarrow \frac{R_2}{R_1} = A_{CL} - 1 \rightarrow R_2 = (A_{CL} - 1)R_1 = 99 \cdot R_1$$

  If R_1 = 10 kΩ then R_2 = 990 kΩ.

- The output of the ADC
  See NWES Module 4.2.6

  $$V_{LSB} = \frac{V_{ref}}{2^n} = \frac{5\ V}{2^{10}} = 4.88\ mV$$

  $$m = \left\lfloor \frac{4.11\ V}{0.00488\ V} \right\rfloor = \lfloor 841.73 \rfloor = 841$$